30. *On the* Moine Gneisses *of the* East-Central Highlands *and their* Position *in the* Highland Sequence.[1] By George Barrow, Esq., F.G.S. (Read March 23rd, 1904.)

[Plates XXXIII–XXXVII.]

Contents.

I. Introduction.

The object of this paper is: First, to describe the Moine Gneisses in Perthshire and Aberdeenshire, and to show that in their mode of occurrence and field-characters, as well as in their composition and microscopic structures, they are identical with the Moine Gneisses of the North-Western Highlands.

Secondly, to trace the mode of ending-off of these gneisses, and to show that, while retaining their characteristic parallel banding they pass into a small zone of rocks, locally known as the Honestones, which, in varying phases, lie persistently for miles on the white margin of the Central-Highland Quartzite. The parallel-banded Moine Gneisses are, in fact, simply the flaggy margin of this Quartzite.

Thirdly, to show, that in this special area, as the flaggy rocks thicken, there is usually a small hiatus in the succession, owing either to the contemporaneous erosion of the finer material that should lie next them, or to its non-deposition. When this parallel-banded material, however, attains a certain degree of fineness, this erosion rarely occurs, and then the other limit of the group is the Little Limestone. In fact, when the succession is complete, the Moine Gneisses can be shown to pass laterally into the rocks of the Honestone Group, and to lie between the white margin of the Quartzite and the Little Limestone.

Whether these flaggy rocks lie above or below the Quartzite is at present a matter of dispute. The view here taken is that they come above the Quartzite, and the evidence for that view will be given in detail.

The area examined extends from the River Garry, between Blair Atholl and the summit of the Highland Railway, in a north-easterly and easterly direction to Glen Girnoch, east of Balmoral in Aberdeenshire, a distance of some 50 miles.

II. The Moine Gneisses.

The district over which the undoubted Moine Gneisses occur may be divided into three parts: (*a*) the Struan area, which lies to the

[1] Communicated by permission of the Director of H.M. Geological Survey.

west of the great Glen-Tilt igneous complex; (*b*) the area lying between the Glen-Tilt complex and the great Cairngorm mass of granite; and (*c*) a tract which forms a small portion of the ground to the south-east of the latter intrusion. These masses of granite are chosen to fix the position of the areas, simply because they are shown on most small-scale geological maps, and are easily recognized.

(*a*) The Moine Gneisses of the Struan Area.

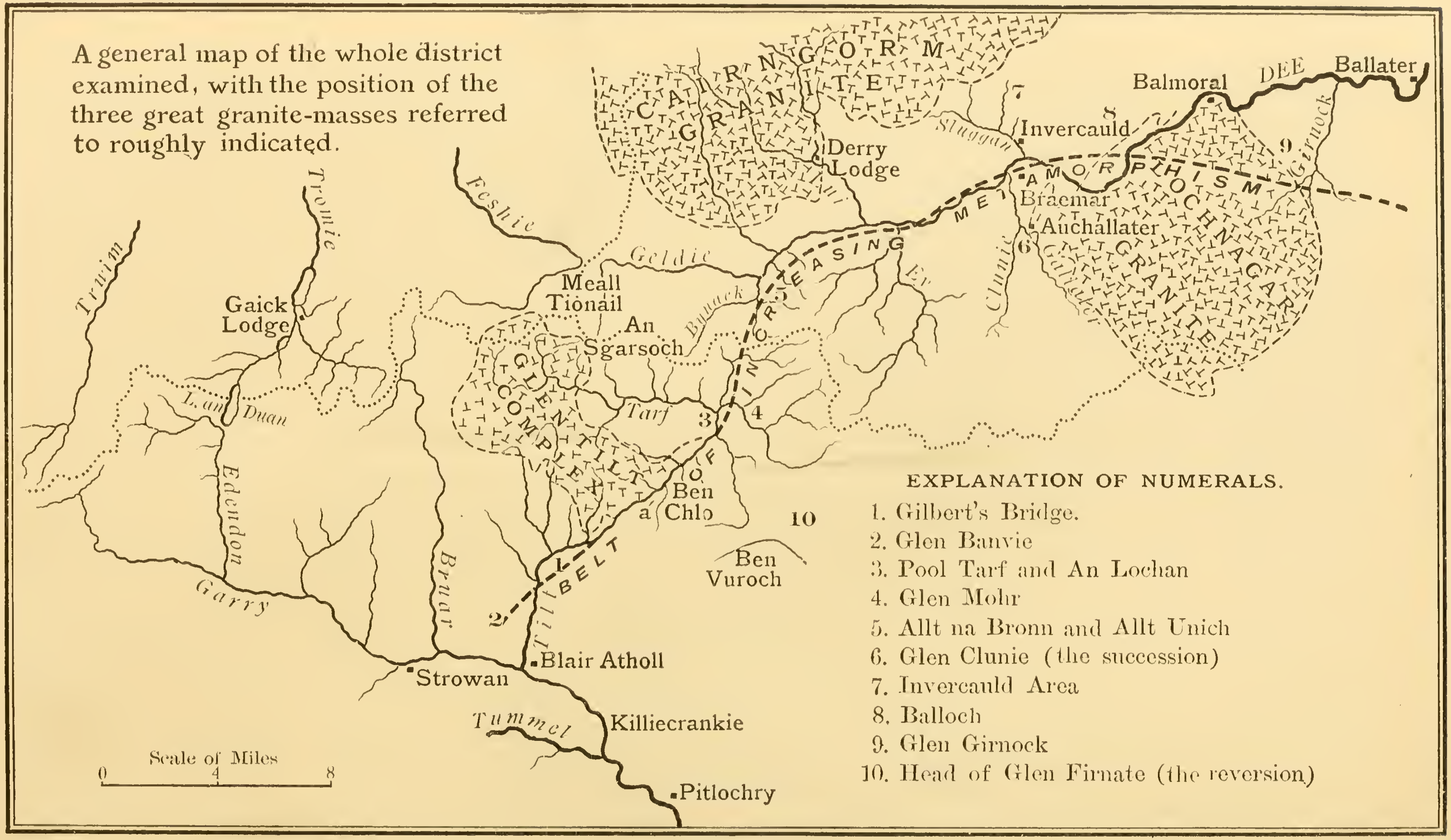
This area is bounded on the west by the River Garry, and, as the sections are easily accessible, it will be convenient to begin with a description of the gneisses there exposed, and to use this as a standard of reference in describing the gneisses elsewhere.

The Garry Section.—Since the days of McCulloch, the River Garry above Struan has been famous for the sections of flag-like rocks which are exposed in its bed and banks, from Struan, almost without interruption, to the summit of the Highland Railway. Its most striking feature is the extraordinary simulation of a normal sequence of enormous thickness, the dip being apparently persistent in one direction (the south-east), at an angle of from 20° to 30°. As seen from a distance, almost the whole sequence consists of well-bedded flags, the component bands varying in thickness, the average of which is about 6 inches, or perhaps less. It will be shown later that thicker bands predominate at one portion of the series, and thinner at another.

The imitation of a sequence of enormous thickness, and the perfect preservation of the parallel banding, together with their highly-crystalline condition, enable these rocks to be easily identified. Since the days of McCulloch, many observers have noted the extraordinary resemblance of the rocks to the flaggy gneisses of the North-Western Highlands, now known as the Moine Gneisses. Further, the mapping of the Highlands has progressed far enough to leave no reasonable doubt that the Struan Flags and the Moine Gneisses are one and the same group of rocks, and it is consequently advisable to recognize this identity in describing them. Additional facilities for their study have been afforded by the cuttings recently made in widening the Highland Railway above Struan, by means of which fresher material can now be obtained for microscopic examination. (See figs. 2 & 3, pp. 404 & 405.)

The Grey Gneiss.—The dominant member of the Moine Gneisses in this area is an evenly colour-banded and markedly-granular, acid gneiss, containing a variable, but often considerable, amount of brown mica. White mica is frequently present in the typical gneiss, but as a rule in smaller quantity than brown, while it is in many bands absent altogether. Though the amount of brown mica varies incessantly, taking the group as a whole, it is for the most part evenly distributed through small thicknesses of the gneiss, varying from a fraction of an inch to sometimes as much as

Fig. 1.



A general map of the whole district examined, with the position of the three great granite-masses referred to roughly indicated.
CAIRNGORM GRANITE
LOCHNAGAR GRANITE
GLEN TILT COMPLEX
BELT OF INCREASING METAMORPHISM
Ballater
DEE
Balmoral
Invercauld
Braemar
Auchallater
Derry Lodge
Sluggan
Girnock
Clunie
Callater
Geldie
Bynack
Feshie
Tromie
Truim
Gaick Lodge
L. an Duan
Edendon
Garry
Bruar
Tarf
Tilt
Meall Tionail
An Sgarsoch
Ben a' Chlo
Ben Vuroch
Blair Atholl
Strowan
Killiecrankie
Tummel
Pitlochry
Scale of Miles
0
4
8
EXPLANATION OF NUMERALS.
1. Gilbert's Bridge.
2. Glen Banvie
3. Pool Tarf and An Lochan
4. Glen Mohr
5. Allt na Bronn and Allt Unich
6. Glen Clunie (the succession)
7. Invercauld Area
8. Balloch
9. Glen Girnock
10. Head of Glen Firnate (the reversion)

2 feet, or even more. This increase and decrease, in different bands, of evenly-disseminated brown mica imparts different shades of grey, pale-grey, or pinkish-grey to the banded gneiss, and is the principal cause of the evenly colour-banded aspect, which is its most characteristic feature. The bedded aspect of the series is often intensified by the arrangement of the individual crystals of biotite parallel to the colour-banding. But it is still further accentuated by the presence of films of felted dark mica, which are always rigidly parallel, and appear on a cross-fractured surface as fine black lines.

These films decompose more readily than the rest of the rock, and give rise to planes of diminished coherence, so that when fragments become detached from a scar-face they break away along those parallel surfaces. Further, this decomposed material weathers out, leaving a series of minute parallel grooves that have the appearance of dark lines when seen from a distance of a few feet. It is, indeed, to the presence of these films that the flaggy weathering of the Moine Gneisses is essentially due; and when the gneisses occur in thicker bands, or the films are much farther apart, the flaggy character is partly lost. It will be shown later that the presence of these films is of the utmost importance in tracing these rocks when they thin away to the south-east.

That these rocks are altered sediments, and that the colour-banding is coincident with the original bedding, is, in many cases, perfectly clear from their chemical and mineralogical composition; but, if any further proof were wanted, it is to be found in the small cross-cleaved, highly-micaceous bands, originally more of the nature of shales, that occur at intervals throughout the whole of the Struan section. This cleavage of the original shale-material obviously took place prior to any crystallization, and, as a rule, it ends abruptly against the colour-banded rocks, which, from their present composition, must have been of a more sandy nature originally, and would not cleave. The phenomenon is identical with that observed so often in cleaved and folded Silurian rocks, although the latter have not since been crystallized. Equally important, from this point of view, is the occurrence in the deep cutting at the Perth 42-milepost of a special type of grey gneiss, in which there is scarcely any parallel banding; even the parallel arrangement of the biotite in the rock is not well marked, and the felted films of biotite are entirely absent. This rock differs from the more common type of gneiss in its mode of weathering, and on open ground forms rounded blocks of massive aspect, somewhat resembling a very fine granite. The absence of any indication of the original bedding suggests that the material was deposited under somewhat different conditions from those of the parallel-banded gneisses. It may be here noted that no thick band of such material ever occurs near the south-eastern margin of the Moine Gneisses, or in the ground where they end off.

It may not be out of place, in concluding this account of the macroscopic character of these gneisses, to draw attention to the

Fig. 2.—*Typical view of the Moine Gneisses in the bed of the Tilt, looking up stream from Gilbert's Bridge.*

[The persistent dip of the flaggy structure and the imitation of a normal sequence are well shown.]

Fig. 3.—*Typical scar formed of Moine Gneisses, showing the resemblance to unaltered sandstones : on the River Garry, near Clune, 2 miles north-west of Struan.*

fact that their highly-crystalline character is shown, not by the quartz or felspar, but by the persistently-large size of the micas, when these are present in notable quantity. Years of study have proved that this is by far the most sensitive test by which to judge of the degree of crystallization in altered sediments, such as were originally normal sandstones and shales.

Microscopic Characters of the Gneisses in the Struan Area.—Great light is thrown on the structure and composition of these gneisses by the aid of the microscope. Taking first the prevalent type—the parallel-banded rocks, we find that they are essentially felspathic gneisses, the felspar being usually in excess of the quartz, and in some cases occurring almost to the exclusion of the latter. As the quartz decreases in amount it tends to assume a rather rounded form, embedded more or less in the felspar, and constituting 'quartz-bleb structure.' It may, when present in very small quantity, occur as minute globules in the felspar, imitating exactly the micropoikilitic structure of igneous rocks. The felspar is of two kinds—microcline, for the most part fresh and showing the typical cross-hatching; and plagioclase, usually much decomposed. It is almost impossible, in many cases, to be certain of the nature of the plagioclase-felspar, but in some instances it is clearly oligoclase. The relative proportion of microcline to plagioclase in the gneisses of the Struan area varies greatly. In the lighter-grey varieties plagioclase seems to be, as a rule, slightly in excess: in the darker-grey varieties, microcline often exceeds the other in amount. When the gneiss weathers with a distinctly-pink edge, the microcline seems usually to be the dominant felspar in this area; and it is, at times, more abundant than plagioclase and quartz taken together. A good idea of the general structure may be obtained by selecting a specimen in which the quartz, microcline, and plagioclase are present in nearly-equal proportions.[1] It will be seen that the grains are, on the whole, evenly distributed, as if they had been first mixed in a pepper-pot and then shaken out. This granular arrangement of the component grains may be described as a 'granulitic structure'; but it cannot be too clearly understood that it is unlike the granulitic structure of many of the schists of the Southern Highlands. The microcline usually retains this granular mode of occurrence, even when present in large quantity, and it rarely helps to bring out the foliated character or parallel structure of the rocks. But, if the plagioclase increases in proportion, it assumes irregular forms, and tends to occur in much larger and often elongated patches that help to define the parallel structure. The quartz in the latter case frequently appears embedded as 'blebs' in the felspar, a mode of occurrence that can often be made out by the aid of a hand-lens.

The foliated aspect, in hand-specimens, of a single band or flag

[1] See Pl. XXXIV, fig. 1 (No. 88). The low numbers refer to photographs in the possession of the Geological Survey; the high ones (10,422) to the microscopic rock-sections.

of the gneiss is mainly due to the parallel arrangement of the micas ; and microscopic sections show that, as a rule, these are so set in the rock as to interfere only to a small extent with the granular structure shown by the quartz and felspar. It is only when mica is present in sufficiently-large quantity to impart an almost-fissile character to the rock, that its influence appears in the rock-structure. In that case, almost continuous films of biotite or biotite and muscovite separate well-defined parallel strips of quartz-felspar material. The edges of the grains in contact with the mica are now distinctly flattened, and, moreover, the grains within the parallel strips tend to assume a somewhat quadrangular form (Nos. 85, 89, & 90).

In the Struan and adjacent areas, the biotite of the Moine Gneisses, when fresh, is always of the normal haughtonite-type—that is, when seen in cross-section and rotated under a single nicol, it changes in colour from brown to a watery-black. Inclusions with more or less pleochroic halos occur in the biotite, although they are not a marked feature of the mineral. Chlorite is present in many of the rocks, more particularly in the micaceous gneisses. It is very difficult to say whether this is a replacement-product after brown mica or not. It is too often forgotten that lime, though in small quantity, is an essential constituent of normal biotite; and, in many cases, the more or less chloritic original material from which these rocks were produced did not contain sufficient lime to form even biotite when metamorphosed, and then the chlorite is the direct product of thermal metamorphism. Pleochroic spots are common in this chlorite. The white mica presents no feature of importance, except in its mode of occurrence. It does not conform to the foliation so closely as the biotite, and in some of the rocks it is set with the basal plane at right angles to the foliation.

In addition to the minerals just enumerated, small crystals of sphene are common in some of the specimens, and present in almost all. They are often pointed, elliptical in shape, and are frequently coated with a film of iron-oxide. They have usually the aspect of metamorphic sphene, and are never strictly original. Apatite occurs occasionally, as also zircon. The latter is not nearly so common as might have been expected in such rocks, which clearly originated from fine felspathic and micaceous sands. Small garnets occur in certain dark blotches in one band of very pale gneiss, but the mineral is not common in this area.

Taking the grey gneisses as a whole, they are remarkable for the amount of microcline present, and, in this respect, they differ from the grey gneisses of the areas farther to the north-east (to be described later), where microcline is less common, despite the close external resemblance between the rocks in the two areas.

The Pink-edged Gneisses.—In addition to the dominant grey-banded gneisses, there are also present some that weather with a pink edge, even though they are grey on a freshly-fractured face. These pink-edged varieties are especially interesting, because they

serve, more than any other members, to correlate the Moine Gneisses of different areas despite local variations of character. It has been found in the Struan and adjacent areas that these rocks are especially rich in microcline. Moreover, when the pink coloration is well marked, they usually contain in addition some calc-silicate, which is most commonly epidote or zoisite, but at times hornblende is present. Typical examples of the epidote-bearing variety are abundant in the second cutting above Struan Railway-station. The most interesting example of this pink type, however, occurs in the bed of the Garry, immediately in front of Dalnacardoch Lodge. Like all the rocks close by, it splits into comparatively-thin slabs, owing to the presence, at short intervals, of the thin films of felted biotite already mentioned. Between these films the rock is not particularly fissile; indeed, it is rather tough, and shows a mottled red-and-green coloration, on a cross-fractured surface. A section shows that it is composed mainly of the typical cross-hatched microcline. This forms a kind of groundmass, in which are set a number of aggregates of green mica, the long axes of which are parallel to, and, indeed, serve to mark, the foliation of the rock. A small amount of plagioclase (in irregular patches) and a little white mica are also present. Apatite is fairly common, and occurs in much the same manner as the quartz. This latter mineral is present in very small quantity, and most of it is found as tiny blebs in the microcline, affording a perfect example of micropoikilitic structure. The occurrence of this rock, so rich in alkali-felspar, is especially interesting, as it tends to recur again and again over a very large area, and apparently at a definite horizon.[1]

The highly-micaceous Gneisses.—These rocks are characterized by abundant white mica and biotite or chlorite. For the most part they are cross-cleaved, as already stated; but where only a very thin parting occurs, the gneiss is at times 'rodded,' that is, the micas are all elongated in a definite direction, and there is no specially-marked plane of schistosity. This variety serves to show that the originally-softer parts of the series have often suffered considerably from dynamic action prior to crystallization.

These micaceous bands possess a somewhat different structure from that of the other gneisses. In the cross-cleaved variety there is a tendency to form lenticles, free from mica, as in the true schists, but the lenticular structure visible in the hand-specimen is not nearly so obvious under the microscope. Comparatively-little microcline is present, and only a moderate amount of felspar. Quartz, on the other hand, is more abundant than would have been suspected. Apatite is much more common than in the parallel-banded rocks. The abundance of quartz explains, what is specially noticeable, the total absence from the micaceous gneisses of silicates of alumina, such as sillimanite, cordierite, andalusite, etc. Clearly,

[1] See Pl. XXXVI, fig. 1 (No. 84). Further investigation has shown that this is the 'Pink Felspathic' rock described on p. 416, and marks the top of the Moine Gneisses.

after the formation of the micas, there was not an excess of alumina sufficient to form such minerals, and the microscope confirms the inference that the shale was originally somewhat gritty and impure.

Other Exposures in the Struan District.

The flaggy gneisses just described cover a large area on both sides of the Garry, above Struan. On the open ground, however, good exposures of them are not numerous, because the flanks of the hills are much obscured by Drift, and the crests of the hills are frequently covered by a somewhat angular rubble, which is due to the disintegration of the rocks. About the Dalnacardoch area, and for some distance eastward, the massive grey gneiss is especially abundant, where it weathers in the form of rounded blocks. Owing to its greater power of resisting decomposition, it is often seen *in situ*. Excellent sections are exposed, however, in the streams that drain into the Garry, and these are often continuous for considerable distances. Microscopic examination shows little variation in the type-rocks; while the appearance of a continuous dip is at times even more marked than in the Garry section.

In the area between Struan and Blair Atholl, the gneisses undergo a slight change, becoming, on the whole, more micaceous, and in many cases rather more fissile. The latter character is shown by microscopic sections to be due to the parallel arrangement of the white mica, as well as of the brown, the two being often in contact. Good examples of this type occur in the cutting near the Manse, north-west of Blair Atholl, where the rocks appear to contain rather less microcline than usual. Around the igneous complex of Glen Banvie, and for some distance to the south-east, the gneisses are rather more quartzose than usual, becoming at times almost quartzites. A typical example of the latter is essentially a granular mosaic of quartz and felspar, with a little brown and white mica, but it differs from the Central-Highland Quartzite in the large amount of microcline present. Farther down the Banvie Burn greyer-banded types occur, well shown in the quarry under the road at the western end of the Whim Plantation. One of these (10,422) contains many oval crystals of microcline, within which are numerous poikilitic grains of quartz, as well as minute flakes of mica and grains of garnet and epidote. Most of the grey bands, with parallel biotite, contain much microcline, but when the biotite is abundant it begins to show a reddish-brown tint. A little band (10,424) having much the appearance of the material that forms the more massive rocks about Dalnacardoch, is also seen here; and it is especially worthy of note that this contains hardly any microcline, but much plagioclase in sheets enveloping the quartz.

Before leaving the Garry area, attention may be drawn to two special rocks. The first occurs in the river-bed at Dalnacardoch, and has already been described (p. 408); the second is associated with the typical grey-banded gneiss, and is composed of white quartzose-looking material, within which are set a number of dark blotches

The latter was first seen in the railway-cutting below the Perth 42-milepost, and later on at the Perth 44-milepost. Mr. Macconochie found it in the bed of the river at Struan and in a number of other places, but it does not seem to be associated with the more massive gneiss. This band, which we propose to call the 'Blotch-Rock,' can be immediately recognized; indeed it has been met with over a large area, and serves to show more than anything else that the rocks composing the colour-banded gneisses were originally quite thin.

Area north of Struan, about the watershed of Perth and Inverness.

As we approach the watershed, the south-easterly dip slowly changes, and becomes northerly. In the Gaick Burn, although the typical grey gneiss is present, most of the bands are thin, and of the type of those seen at Dalnacardoch. Three varieties of these thinner bands are worthy of special notice. One is a kind of spangled gneiss, and contains a considerable amount of biotite, and at times a few crystals of muscovite at right angles to the banding (11,055). From its mode of occurrence, we may assume that it was almost certainly a shaly rock originally, but its dominant constituent now is well-crystallized microcline, which forms 60 per cent. of the rock. There can be little doubt that this microcline in such a rock results mainly from the action of finely-divided micaceous material on finely-divided quartz, thereby forming microcline; for it will be seen later that this excessive amount of microcline, in many cases, characterizes the limestone and the adjacent shales. A specimen, on the other hand, with much white mica contains little alkali-felspar, suggesting that in this case no such interaction took place (11,058). Associated with these, is a little band containing epidote along certain lines. But one of the most striking features of the exposures about the Gaick Burn is the frequent repetition of the little 'Blotch-Rock,' showing that over a large area we do not move more than a few feet from one horizon in the original sequence.

Near the watershed the more thinly-banded rocks slowly disappear, and the normal grey gneiss is again met with. The most abundant phase (11,052) is rather light-grey in colour, with quartz-grains, somewhat rounded 'quartz-blebs' set in a matrix of felspar, most of which is the typical microcline (97). Some plagioclase is present, mostly decomposed. A somewhat darker phase (11,053) contains slightly less microcline, with more quartz, and in this the 'quartz-bleb' structure is not so well shown. In both, the mica shows the usual parallel arrangement; the typical small sphenes are fairly abundant, while minute zircons are more numerous than in most of the specimens from the Garry area.

(*b*) Area East of the Glen-Tilt Igneous Complex.

In the Perthshire portion of the area east of the Glen-Tilt complex, several important differences in the Moine Gneisses are

visible, as compared with those already described; and, in addition, small outcrops of other members of the succession are met with, by the aid of which the position of the parallel-banded gneisses can be fixed. A distinct, though slight, change in composition is shown by the increase of biotite in the rocks as a whole; and this is accompanied by the development of sillimanite in some of the more micaceous thin partings, thereby fixing the phase of crystallization. Obviously, the original material had become more muddy on the whole, and less of a fine arkose or sand, though the latter character was still retained in one part of the group.

Two types of the gneiss in this area are worthy of special notice. The first weathers with rounded outlines, is of somewhat massive aspect, and resembles a fine granite. It forms the long, rounded ridge stretching from An Sgarsoch, at the county-boundary, in a southerly direction to Sron na Macranach, on the north side of the Tarf. Considerable masses of similar rock occur on Cairn Fidhleir, farther west. This tract lies in a line with the other outcrops of the massive, round-weathering gneiss already mentioned, of which it seems to be a slight modification. Sections of these rocks show that they contain singularly-little microcline and an unusual amount of plagioclase (mostly oligoclase), often fringed with vermicular pegmatite, and at times partly idiomorphic with respect to the quartz (11,059).[1] In both localities, the round-weathering type of gneiss is succeeded by a singularly-flaggy phase, in which microcline is abundant and parallel structures are well marked: thus strongly suggesting that the rock so rich in plagioclase marks a distinct horizon. As in the Struan area, thin bands of somewhat similar material occur to the south-east: and in these the plagioclase has frequently much vermicular pegmatite on its margin, forming clubbed ends to the narrow crystals (11,066).

The second type of gneiss of special importance in this area is sharply separated from the normal phases hitherto described by the occurrence within the individual bands of a lenticular or 'thrust-plane' structure, similar to that met with in the grits of the Southern-Highland border, and due to mechanical deformation. A typical specimen (11,076) is a grey gneiss with thrust-plane structure, in which the movement-planes are coated with dark mica. It is composed of abundant oligoclase and quartz occurring together in lenticles, separated by films rich in reddish-brown mica. These films alternately approach and recede from each other, and show the typical undulatory parallelism of a true schist of the Southern-Highland type. The occurrence of this structure is highly important, as it shows that when the material of the Moine Gneiss was strongly affected by dynamic action, the rocks crystallized as typical lenticular or phacoidal schists. It is a fair inference, that the persistent absence of any such structure from the typical grey gneisses is conclusive evidence that they suffered practically no mechanical deformation prior to crystallization within the individual

[1] See Pl. XXXV, fig. 2 (No. 107).

bands, though considerable sliding may have taken place along the greasy chloritic parting-films. The belt within which this structure occurs commences at the Tilt Valley, on both sides of the Tarf, and stretches to the foot of Sron na Macranach. It will be described in detail in the Survey memoir on the district.

Aberdeenshire Area, west of the Lochnagar Granite.

The feature of this area, on the whole, is the perfection with which the parallel structure is shown in the field, especially in stream-sections; the bands are perhaps thicker than in the Garry area, and they have a singularly-massive habit, owing to which they may be described as of the 'massive-pavement' type. These massive pavements are admirably shown in the bed of the Geldie above its junction with the Dee, where the river runs approximately parallel with the strike. The dominant type of gneiss is grey, and highly crystalline. Granulite and quartz-bleb structures are common in many of the rocks, and they contain, on the whole, little white mica. The biotite varies: sometimes it is normal haughtonite, but more often it is of the reddish-brown type. Garnet occurs in microscopic sections more frequently than the external appearance of the rocks would lead one to expect. Plagioclase-felspar is far more abundant than microcline, though here again there is one horizon at which the latter is fairly abundant. Three types are worthy of special reference. The first is a banded grey gneiss (8512), in which Dr. Teall noted a line specially rich in iron-ore and zircon, clearly indicative of original bedding and parallel to the colour-banding; it is a typical granulite, with no trace of quartz-bleb structure. The second is remarkable for the number of small pink garnets in it, which enable the band to be easily identified (8510). Like the 'Blotch-Rock' of the Struan area, this little garnet-band has been met with again and again over the area west of the Cairngorm Granite, thus indicating that the whole group was originally of no great thickness. The third type is a pink-edged epidotic gneiss containing much microcline, which, though present over a limited area, is abundant close to the margin of the granite, and specially so near Monadh Mor, just inside the boundary of Inverness-shire. A typical specimen (8519) is almost identical with (8518) from the Allt Unich, south of the Geldie, which, on account of its importance, will be referred to again (see p. 436).

Area flanking the Dee above Braemar.

In and about the Allt Unich, just mentioned, a considerable portion of the Moine Gneisses is highly quartzose, and differs markedly from the typical grey- and pink-banded rocks, which are here present only in subordinate quantity. This is due to the fact that the flaggy gneisses are here largely composed of the Central-Highland Quartzite, exhibiting many of the curious structures so characteristic of the Moine Gneisses. Although these quartzose rocks possess a flaggy aspect on the whole, it is not so marked as in

the parallel-banded grey gneisses; for the typical highly-chloritic films of the latter were never present in the original quartzite. On the splitting-face a thin film of fine, evenly-disseminated muscovite is present, which gives rise to the flaggy aspect of the quartzose gneiss. It was doubtless developed along buckling-planes from the felspar in the Quartzite. This type of material is the dominant constituent of the Moine Gneiss on the south side of the Dee, for a considerable distance to the east.

Approaching Braemar, the colour-banded pink-and-grey rocks increase once more in amount; but still, in small openings by the roadside, portions of the true quartzite can be identified, despite the new structure developed in it, by certain fine dark lines of heavy minerals, to which special reference will be made in describing the Quartzite.

(*c*) Area south-east of the Cairngorm Granite.

In that portion of Invercauld Forest which lies between the Sluggan Burn and the ridge of Cairn Liath to the east, the Moine Gneisses vary somewhat in appearance. Highly-quartzose rocks are more abundant in the south-eastern part of this ground, and the bands are distinctly thinner; but farther to the north-west they thicken and, on the whole, become more felspathic and variable in composition. Where thinner, they consist essentially of three small bands: the first being practically quartzite, the second darker with more brown mica, and the third a kind of pink-edged quartzite. These three thin bands, by repeated foldings on themselves, form great rock-masses, which can be admirably studied in the low crags alongside the Sluggan-Burn footpath, at about a mile above the junction with the Dee.[1]

A little to the south-east of these crags, it is again often impossible to say where the Moine Gneisses end off and the Central-Highland Quartzite begins; for the latter now occurs in a 'Moine-phase.' The typical white margin of the latter can be identified on the footpath above the house, near the northern end of the plantations; and, starting from this point, it is clear that the greater part of the quartzose gneiss must be formed of the Main Quartzite.

On the ridge between Meall Gorm and Cairn Liath, little but the three quartzose bands already mentioned can be seen. The palest band is met with first, and is just sufficiently banded to be separable from the true Quartzite. Farther north the greyer band appears, slowly becoming more felspathic and more like the typical grey gneiss. On the southern part of Cairn Liath, the pink quartzose band is the dominant rock, and must be folded on itself to an extent that is almost incredible, to form so large a portion of this hill. Farther west, the thickening and the change in composition are soon well marked: the pink-edged rock in particular having darker and more felspathic bands in it. One of these has a rather mottled

[1] See p. 435 for a description of these bands where the Moine structure is not developed.

aspect, and possesses the typical granular structure of a Moine Gneiss; it is composed of both potash- and plagioclase-felspar, which together exceed the quartz in amount. Biotite is fairly abundant, and epidote occurs along certain lines. This is the typical pink-edged epidotic gneiss, which occurs over a wide area. Still farther west, both angular and round-weathering grey bands appear; but the pink-edged rocks still predominate, always containing a considerable amount of potash-felspar, the latter often fringed with vermicular pegmatite. Closer to the head of the Sluggan Burn, infolds of more highly-quartzose rock are met with, and increase in size, until the large mass separated-out on the map is reached, which is once more, in the main, the Central-Highland Quartzite, with the Moine-Gneiss structure superimposed on it.

On the south side of the Dee, to the east of Braemar, the old difficulty recurs in separating the true Quartzite from the highly-quartzose Moine Gneiss; but a faint remnant of the typical, parallel-banded, grey material is seen in the little quarry, close to the gate of the footpath that passes on the south side of Creag Choinnich.

One of the few cases in which the Quartzite in a 'Moine-phase' can be separated from the quartzose gneiss is met with on the hill-top above Balloch Farm, some 2 miles north-east of Invercauld; the latter being seen practically in contact with the white margin of the former. The best locality for studying this is between the limestone and the small mass of diorite and granite,[1] farther west.

Summary.

This account of the Moine Gneisses may be summed up briefly as follows:—

1. These gneisses are a parallel-banded series of sedimentary origin, usually rich in felspar (largely microcline), and containing dark biotite in variable quantity.
2. The gneisses are thinly-bedded, as a whole; and their structure is essentially parallel, but not lenticular or phacoidal. This parallel structure is in most cases shown by the arrangement of the biotite.
3. Certain types can be recognized again and again throughout the whole area; and their repeated occurrence shows that the whole series is really thin, although by intense folding it simulates a succession of enormous thickness.
4. Although the variation in the typical grey gneisses, as they are traced eastward, is not great, still it is important. Biotite is, on the whole, more abundant; and the highly-micaceous partings become more aluminous, that is, were more of the nature of fine mud originally.
5. A striking feature of the grey gneisses is seen in the films of felted biotite, derived from original clastic chlorite, and

[1] The position of these rocks is shown on the Geological-Survey 1-inch map, Sheet 65, to be published shortly.

indicating the former bedding-planes. Their presence is highly important, especially when we consider the mode in which the Moine Gneisses end off when traced to the south-east, as it will be seen that they link the gneisses with the Dark Schist, of which the same material was an abundant constituent.

6. Lastly, a considerable mass of highly-quartzose material, which, for purposes of mapping, must be included in the Moine Gneiss, can in the eastern part of the area be shown to be really the Highland Quartzite (in what may be conveniently called a 'Moine-phase'), and should be excluded from the group in discussing the origin of the grey gneisses.

III. Mode of Ending-off of the Moine Gneisses.

Having shown that these gneisses extend in a south-easterly direction to the Tilt Valley, the Geldie, and the Dee, almost to Braemar, we may pass on to consider the question why they do not appear in their typical phases to the south-east of this long line. The simplest explanation would be that they have been faulted-out; and in the Glen-Tilt area this, at first, seems to be the true one. That it is not sufficient, however, is clear from the fact that in some cases the gneisses cease to be recognizable before the main fault is reached, while in the district east of the Geldie they cross the fault in mass. Two other causes may be suggested: first, that they become less crystalline, and so cease to be recognizable as Moine Gneisses; or, secondly, that they thin away. It will be shown that both causes co-operate to render the further tracing of them a matter of difficulty.

(*a*) The Belt of Decreasing Crystallization.

The first of the causes above suggested is most important in the Tilt Valley, where the decrease in crystallization is unusually rapid. It occurs along a belt that has been traced from the coast north of Stonehaven to a point north-east of Blair Atholl, a distance of about 100 miles. This belt passes in a somewhat curving line from the eastern coast to the head of Glen Isla, where it sweeps round in a north-easterly direction almost to Ballater; thence it turns westward, and crosses the Dee somewhere between Balmoral and Braemar. From the latter point it coincides roughly with the Dee Valley as far as the Geldie Burn, after which it follows, approximately, the belt of faulting in the Tilt Valley to within 3 miles of Blair Atholl. West of the Geldie, this area of decreasing metamorphism corresponds approximately with the belt along which the Moine Gneisses disappear; but east of the Geldie the two are less intimately connected. When this belt of decreasing metamorphism attains its full development, we pass from the 'sillimanite[1]-aureole' to that characterized by the presence of kyanite and

[1] See 'On an Intrusion of Muscovite-Biotite Gneiss in the S.E. Highlands of Scotland' Quart. Journ. Geol. Soc. vol. xlix (1893) p. 332.

staurolite: but on either side of the belt the metamorphism remains singularly constant over very large areas.

In the Tilt Valley, as the gneisses are followed, they lose rapidly their crystalline character. But, in addition to this, they also thin away and change in composition, passing into a thin group of equally parallel-banded rocks, known locally as 'the Honestones.'

To establish clearly and fully these changes in the aspect of the Moine Gneisses, it was necessary to find a more or less continuous section that should at once show both the decreasing crystallization and the decreasing thickness. Such a section has been found in the Tilt Valley, in the neighbourhood of Gilbert's Bridge, where the river, instead of continuing its usual rather straight course, makes a big bend toward the north-west. Now the arch of this bend is at one side of the belt of decreasing metamorphism and thickness, while the two ends are at the other; and it is by means of this section that the whole explanation was ultimately arrived at.

(*b*) The Section at Gilbert's Bridge.

(Map, Pl. XXXIII & fig. 9, p. 444.)

Standing on Gilbert's Bridge, and looking up the Tilt, we see a typical section of the parallel-banded gneissose flagstones or Moine Gneisses, striking up-stream, and having an even dip to the south-east, at about 30°. Below the Bridge the same rocks are seen for a few yards, but farther down only small patches of gneiss are exposed, as the rest of the section is composed of numerous infolds of other beds. An examination of the river-channel shows that these rocks are intensely folded, one of them, consisting of limestone, being repeated no less than eight times in a distance of 150 yards. This bed may be either in contact with the Moine Gneiss (here, at times, highly quartzose) or separated by one or all of three beds or bands. Of these, the most striking is a curious 'pink rock,' of which the dominant constituent is obviously felspar. Another is a dark and often tough schist, which varies somewhat in aspect; while the third is a little sill of hornblende-schist, which, by folding on itself, may attain a thickness of more than 6 feet, but is sometimes not seen owing to a slight change of horizon, one of its characteristic features. This little sill is of considerable importance, as fixing, approximately, the horizon with which we are dealing.

The 'Pink Felspathic Rock,' or rather material (for it is found in the other sedimentary rocks) consists mainly of microcline. Where purest, it forms a separate band, which, a little below Gilbert's Bridge, attains a thickness of 6 feet, owing, partly, to repetition by folding. Some way below the Bridge it occurs as lenticles in the quartzose rock. It is evenly disseminated through part of the limestone in one place, while at another it forms a segregated patch, which has so completely recrystallized as to simulate a pegmatite, a mode of occurrence that has been noted over a wide area. A specimen from the thicker band (10,534) is composed of abundant microcline, quartz, decomposed felspar, and a considerable quantity of green and brown mica, with a parallel arrangement. In some

portions of this band microcline is even more abundant, the principal accompaniments being green mica and granular sphene.

The Dark Schist occurs as discontinuous patches that lie next the Limestone, and between it and the 'Pink Felspathic' material, when both are present. These dark patches have proved of exceptional importance, and will be discussed later on.

The Limestone varies greatly in composition. As a rule, however, it contains some snow-white, coarsely-crystalline calcite, and this may be present in separate thin bands or mixed with other minerals. In no case does this rock possess the grey coloration of the typical Blair-Atholl Limestone and the Loch-Tay Limestone. One of the thicker exposures (10,526) contains abundant epidote and microcline, the latter mineral identical with that of the Pink Felspathic Rock, and a small quantity of either optically-anomalous garnet or idocrase. In one place the calcareous material is obviously mixed with a pink felspar, forming a coarsely-mottled pink-and-green rock. The green mineral is malacolite, and the pink the typical microcline.

At the junction of the tough Dark Schist with the base of the limestone occurs a finely-banded rock. The paler bands are composed of abundant epidote and zoisite, with a smaller quantity of hornblende and calcite. The darker films were more aluminous originally, and are now composed of plagioclase and quartz, associated with chlorite and biotite. There are small spots in this part of the rock, dusted over with minute biotite-flecks, exactly as in a typical hornfels.

It is thus apparent that the Limestone has not always the same rock at its margin, and does not always rest upon the Moine Gneiss; and there is clear evidence of a slight local erosion, or a small hiatus in the succession.

After a thorough investigation of the section below the Bridge, the section above it may be examined. The rather massive and highly-crystalline Moine Gneisses occupy the bed of the stream,[1] but the Limestone lies in the bank above, and its base is exposed in places, while at the mouth of the little burn at the northern end of Dalginross Wood, both the felspathic rock and the Limestone are seen. At the base of the latter is a finely-banded, markedly-fissile rock. This fissility is due to the perfect parallelism of a large number of pale-brown micas, associated with a small quantity of actinolite. The rock is structurally a fine quartz-felspar-biotite-granulite, with a considerable amount of microcline, and a little carbonate and granular sphene (10,528). It is of considerable importance, as suggesting a passage to the felspathic material, and recalling the rock at Dalnacardoch and the Gaick Burn.

A few yards farther up the main stream the Pink Rock is seen again in contact with the Moine Gneisses, and continues in this

[1] See fig. 2, p. 404. For the photographs, from which this figure and figs. 3 & 5 are reproduced, I am greatly indebted to Mr. Lunn, of the Geological Survey.

position for some distance. Immediately below the big bend at Auchgoul it changes suddenly in composition, in a manner that seems to exclude the probability of an igneous origin.

The big bend just mentioned is cut in Drift, but at its northern end, the Limestone, repeated several times by folding, is seen either close to or touching the Moine Gneiss. One outcrop of limestone is so much purer, and more like the normal Blair-Atholl Limestone, that it seems at first difficult to believe that we are still dealing with the same bed.

Opposite the mouth of Glen Mhaire the river once more flows along the strike of the rocks, and the Moine Gneisses are now seen to be rather more quartzose and more finely-banded. In the bank close to and above the river are several infolds of the Limestone, associated in one case again with the Pink Felspathic Rock. A few patches of tough Dark Schist, almost a Moine Gneiss at times (10,548), intervene between the Limestone and the Gneisses. In the next long bend, immediately above Glen Mhaire, the river flows exclusively over the Gneisses, which now lie to the north-west of the last outcrop of the Limestone. Beyond this bend, to the north-west, the Moine Gneisses stretch for many miles in an unbroken sheet.

A peculiar interest attaches to this section, for the curve of the bend penetrates more deeply than usual into the belt of increasing metamorphism; and, comparing the rocks at the centre with those at the two ends, the contrast, both in crystallization and thickness of the bands, is well-marked. Moreover, if the steep bank at the south-eastern extremity of this bend be ascended for a short distance, the decrease in crystallization and the thickness of the bands are still better seen. A similar change may also be noted in the small quarry close to the roadside, just at the commencement of the next bend.

A little farther on, in the river-bank, the Limestone is clearly seen, lying in an eroded hollow in the now-attenuated representative of the Moine Gneisses; while apparently above the Limestone is the Dark Schist, but in reality this is a deception, the meaning of which is explained on p. 431. Still farther up the Tilt, the slow decrease in the crystallization of the gneisses may be noted, as fold after fold of the Limestone is crossed. Accompanying this change is an alteration of the material of which the gneisses were originally composed. It is obviously becoming more of the nature of a sandy mud.

We now reach the famous section of the Glen-Tilt Marble-Quarry, known to geologists since the days of Hutton, Playfair, McCulloch, and Murchison, who noted its resemblance to certain limestones and their associated rocks in the North-Western Highlands.[1] Here the Limestone is folded again and again on itself, so as to form a rather thick mass; next to it comes the little sill of hornblende-schist,

[1] See Quart. Journ. Geol. Soc. vol. xvii (1861) p. 223, second footnote.

seen at Gilbert's Bridge, and many other parts of the section already traversed. This, in turn, is succeeded by the Parallel-Banded material (10,556), now obviously an even-banded alternation of fine sandy and muddy sediment. This rock can be at once identified; it is a phase of the Honestones, a well-known member of the Highland Succession. The Limestone itself is of special interest, not only for its beauty, for which it was once so famous, but also from a peculiarity in its composition. It contains a considerable amount of serpentinized forsterite along certain bands. The rock was cut parallel to these bands, so that, when set up, it gives the deceptive appearance of a thick mass of serpentine. A little farther up the river, the thinness of the parallel-banded Honestones allows the white margin of the Quartzite to come into view, and the two are seen folded together again and again, almost to the end of the sharp bend, where the extraordinarily-straight and deep portion of Glen Tilt commences. In this part of the section it will be noted that the Honestones vary somewhat in composition, being slightly more siliceous at one point than at another. They vary also in thickness, and in one place either thin out entirely or become a mere film, so that the margin of the Limestone is almost, if not quite, in contact with the Quartzite. Just before reaching the sharp bend already mentioned, we suddenly come upon a good-sized exposure of the typical bluish-grey Blair-Atholl Limestone, and it seems at first incredible that this can be the same limestone as the one so often referred to; but in the course of some recent traverses it was clearly proved that they are really one and the same. A little farther up the stream the Limestone is succeeded by the Dark Schist, rich in kyanite, that is so abundant in portions of the Braemar area, and all trace of the Moine Gneisses close to the Limestone has now disappeared.

This long section thus clearly shows that the parallel-banded Moine Gneisses, as they cross the belt of decreasing crystallization, not only become less crystalline, but that they gradually change in composition, passing into the 'Honestones,' which were originally a finer and more muddy type of sediment, slowly thinning away as they do so. Where present in mass, the original thickness is so enormously increased by folding that only one side (that next the Limestone), whether top or base, can be seen. When, however, they have become very thin, the other side also is visible, and the rock that lies next this is the fine white margin of the Quartzite. It is thus clear that the Moine Gneisses lie between this Limestone and the Quartzite, and that they may be regarded as the flaggy margin of the latter. Sections have been made to illustrate the progressive change in the nature of the original material of the Moine Gneisses. The first (10,555) was taken from the small quarry close to the road, above the junction of Glen Mhairc with the Tilt. It is a fine-grained banded rock, built up of alternate layers of quartzose and grey granulitic gneiss, or perhaps schist, for the decreasing crystallization to the south-east already begins to be noted here. The structure of the part of the rock that has been cut is

essentially that of a very fine or less crystalline Moine Gneiss, but there is little microcline present, and the biotite is reddish-brown. Another specimen of the more muddy, but still parallel-banded material, was taken from the Tilt close to Marble Lodge (10,556). This is grey throughout, but the darker bands were clearly finer mud originally. These are rich in red biotite and white mica associated with plagioclase, in exactly the same way as in parts of the Dark Schist to be described later. The lighter bands are composed of quartz and decomposed plagioclase, with a little microcline, and possibly some orthoclase. A little biotite, chlorite, and white mica are also present. This rock thus forms a link between the more quartzose, banded material and the curious felspathic and micaceous rock, containing much dark dust, which is so typical of the Black Schist near the Little Limestone.

Returning to the little stream, above Gilbert's Bridge, at the northern end of Dalginross Wood, and examining its bed, we find the change in the nature of the parallel-banded rocks taking place far more rapidly, for we now cross this zone at right angles, instead of diagonally.

The section below Gilbert's Bridge shows phenomena essentially similar to those already recorded. It is, however, far more difficult of access, and the absence of bends, and the fact that the river runs more nearly along the course of the strike, make the progressive change less clear. There are, nevertheless, a few points of special interest. The band nearest the limestone in the Moine Gneisses is often a pure white quartzite, which can be distinguished from the white margin of the Main Quartzite only by the fact that it does not weather rusty-brown. As before, small patches of Dark Schist occur occasionally between the Limestone and the Gneiss, and one of these, 250 yards below the bridge, contains a considerable quantity of kyanite.

At the sharp bend of the Tilt in Crombie Wood (see map, Pl. XXXIII) there is an especially-fine exposure of the Pink Rock, partly in thin pure bands, partly commingled with other material. A little south of Crombie Burn, on the west side of the Tilt, is a small scar, composed of very finely-banded and much less crystalline material, showing that a change takes place below Gilbert's Bridge similar to that already described above it. The stages of the change are not, however, so well seen, and the decrease in crystallization is not so rapid.

(*c*) The Banvie-Burn Section.

A section somewhat similar to that of Gilbert's Bridge occurs in Banvie Burn, at the Whim Plantation, to the north-north-west of Blair Castle. At the western edge of the wood, close to the burn, the typical Moine Gneisses are exposed in a quarry (already referred to, p. 409), and, descending the stream from this point, we cross the usual parallel-banded rocks, locally more siliceous, until we reach

the first outcrop of the Limestone. Between this point and the next bridge, a distance of 250 yards, the Limestone is repeated no less than seven times by folding. As before, no two of these outcrops are exactly alike; but in this case the apparent suddenness of the change is considerably increased, owing to the fact that we now cross the folds at right angles. Certain materials, such as pale hornblende, calcite, granular sphene, etc., are rarely wanting; microcline may be either abundant or absent. The second outcrop, above the lower bridge, is mainly composed of very pale-green hornblende, while that next the small mass of hornblende-schist contains idocrase, garnet, and pyroxene. Below the hornblende-schist the limestone is coarsely mottled green-and-white, the green patches consisting of radial bundles of pale hornblende. The western-most outcrop is a nearly-white and rather siliceous limestone, identical with that seen in several places below Gilbert's Bridge, and in many other localities; while that part of the Moine Gneiss which is next the Limestone is also highly quartzose.

Again, as in the Gilbert's-Bridge section, small patches of Dark Schist, varying both in thickness and composition, occur locally between the Limestone and the Moine Gneiss. The 'Pink Rock' is also present in one place, commencing as a thin infold at either end of the small mass of hornblende-schist, and thickening towards the centre of the outcrop. Here it seems to merge insensibly into the top of the Moine Gneiss, which just appears, in the bed of the river (10,521).

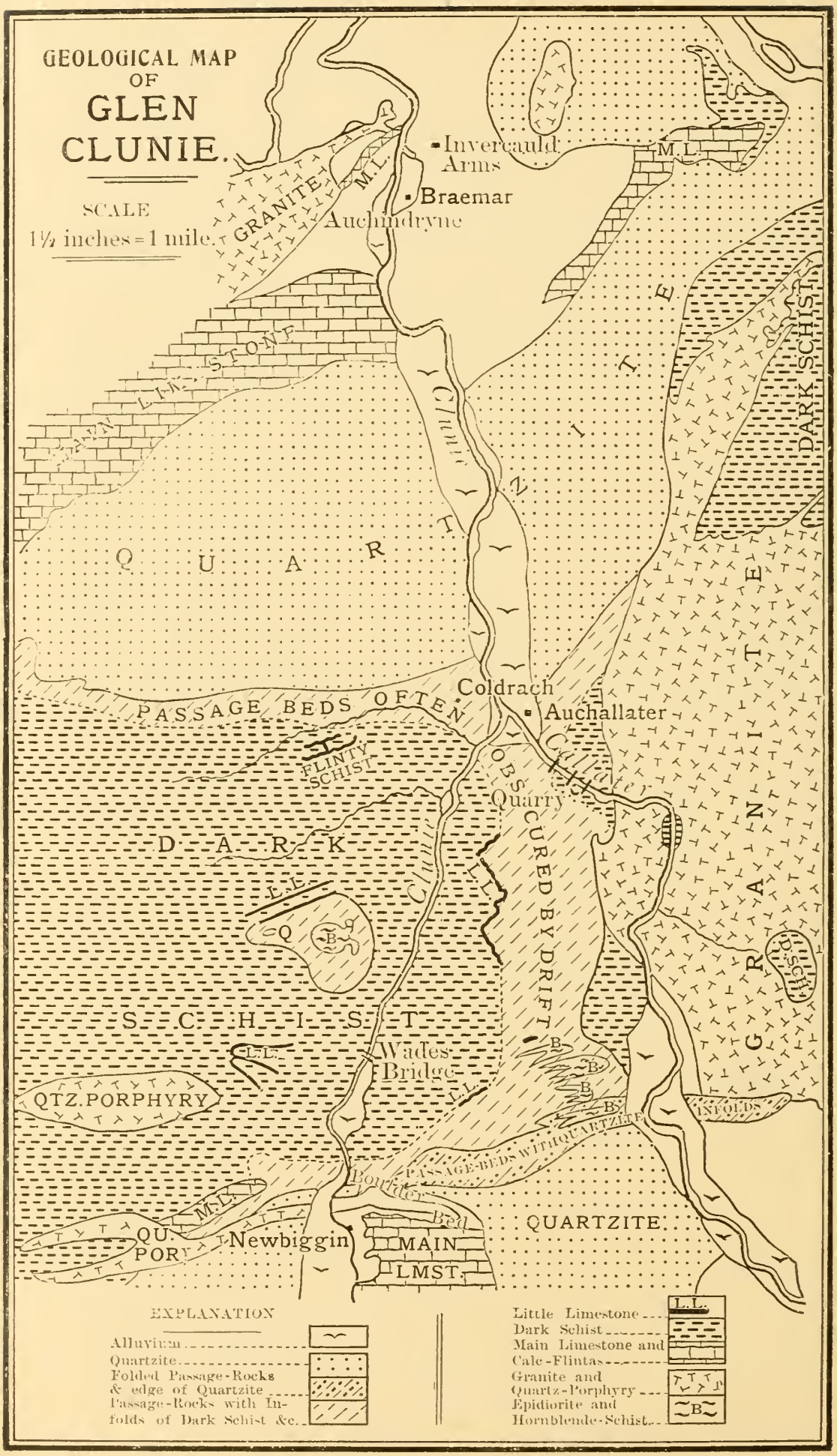
(*d*) The Hiatus in the Succession.

The rocks associated together in the sections hitherto described are as follows:—

1. The Limestone.
2. The Dark Schist (in lenticles).
3. The Pink Felspathic Rock.
4. The Moine Gneisses; elsewhere the Honestones.
5. The Epidiorite-sill, not always at the same horizon.
6. The white edge of the Quartzite, succeeded by the main bed.

It has already been noted that the Limestone may be in contact with any of the first five bands, and in one place it almost touches the last, if it does not quite do so. There must consequently be a small hiatus or line of erosion at the base of the Limestone. But, in addition to the bands enumerated above, there are others present in certain parts of the Aberdeenshire area, and apparently absent here. It is consequently advisable now to fix exactly the order of succession of the rocks, to ascertain the extent of the hiatus, and see how far it throws any doubt on the fact that we are dealing in the main with a regular succession. As the full sequence is exposed in the area south of Braemar, which lies in the belt of ground under investigation, this succession in the Braemar area may now be conveniently described.

Fig. 4. *(See note on p. 423.)*



(*e*) The Succession in the Braemar Area.

The Sequence.—One of the most striking features of the scenery of the East-Central Highlands is the great chain of quartzite-mountains that stretches from Beinn y Ghlo, near Blair Atholl, to Mor Shron, close to Braemar. Parallel to this are minor chains, composed of the same material. While the quartzite is intensely hard, and resists denudation, the rocks associated with it, and in particular a bed of limestone, are much softer, and yield readily to erosion. These beds, in consequence, have weathered away to a great depth, and hence much of the district is characterized by an alternation of high ridges and deep valleys; the trend of which is determined by the strike of the outcrops of the Quartzite. It is with the composition and order of succession of the rocks forming this special type of scenery that we have now to deal. The locality selected for the purpose lies 2 miles south of Braemar; but other parts of the district will be referred to, for the purpose of aiding the investigation.

The succession in this group of rocks, in this area, whether ascending or descending, is as follows:—

1. The Central-Highland Quartzite.
2. The Parallel-Banded Series: Honestones, etc. (passing into Moine Gneisses).
3. The Little Limestone.
4. The Dark or Leaden Schist.
5. The Main Limestone.
6. The altered, parallel-banded Calcareous Shales (Calc-Flintas).

1. The Central-Highland Quartzite.—The Quartzite was originally a bed of sandstone, more felspathic in some parts than others, that has been intensely folded on itself, so as to build up enormous masses of highly-quartzose rock. It is conveniently called a 'quartzite,' because, however much recrystallized, it almost always retains the angular weathering of an ordinary quartzite. Often there is no sign of the mechanical deformation usually met with in the other members of the series; and it is clear that it was altered to a quartzite, not only before the crystallization of the Highland rocks took place, but prior to their crushing. Over almost

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Note on the Map, fig. 4, p. 422.—In this map the sequence is built up. Here, again, the stream and scar-sections are mostly clear, but the flatter ground is greatly obscured by thin peat and Drift; owing to the intense folding, there is often no sharp junction between the different rock-groups. Starting from the margin of the Quartzite, we sometimes see, first the edge of the Quartzite repeatedly folded with the Passage-Beds, then the Passage-Beds folded with the Little Limestone and Dark Schist, and, finally, the Dark Schist only. There is, however, in many cases, a fairly-sharp junction with the Quartzite. The line separating the Passage-rocks from the Dark Schist often implies simply that one rock is the dominant component on one side of the boundary, the other rock on the other. The outcrop of the Little Limestone is so narrow as to be often untraceable. The quartz-porphyry outcrop, shown west and north-west of Newbiggin, also extends to the east of the burn, immediately north of the Main Limestone.

the entire area, the Quartzite varies little in appearance and composition, and can be divided up into three parts, as follows:—

(*a*) The fine white edge of the Quartzite, characterized by its whiteness and its generally-fine grain, and usually containing but little felspar. There is often present, however, a considerable amount of unevenly-distributed pyrites, which, on decomposition, imparts a rusty-brown aspect to this portion of the rock, and this rusty aspect is even more characteristic than the unaltered white colour. It cannot be too clearly understood that this is the only margin of the Quartzite ever met with in the whole of the area under discussion; the reverse side, whether the top or the base, is never seen.

(*b*) The Quartzite, with dark lines of heavy minerals.—This part contains a little more felspar than the last, although still practically white. The fine dark lines in which the heavy minerals occur ndicate the bedding; at times they show that the rock was originally false-bedded.

(*c*) The porous Quartzite.—This portion of the rock, which commences some 6 or 8 feet from the outer margin, must have been coarser originally, and contains more felspar; at times it is markedly felspathic. Owing to the indestructible nature of the quartz, the felspar in an exposed face weathers out completely, leaving a number of small holes in a homogeneous mass of quartz, and imparting to this weathered face its typical porous aspect.

The white edge of the Quartzite can be recognized in almost every clear section, south of Braemar, where the junction with the other members of the series is exposed. In what may be conveniently termed the type-locality, it occurs close to the roadside north of Coldrach. The other parts of the bed may be seen by ascending almost any of the quartzite-mountains in the neighbourhood.

2. The Parallel-Banded Series.—Immediately next the white edge of the Quartzite is a rock composed of a few thin, yellowish, quartzose bands, separated by pale, cross-cleaved, micaceous films: obviously a passage-rock. This is succeeded by greyer material, still in alternating layers of more siliceous[1] and more micaceous composition, the latter again often cross-cleaved. In addition, the face of the micaceous bands is often covered with small spots or projections, proved in many cases to be minute garnets. As we recede from the main Quartzite, the micaceous material darkens in colour, and becomes more like the Dark Schist above; moreover, it exceeds the grey siliceous material in amount.

The section here seen differs from the typical Honestones in the greater proportion of shaly material between the more siliceous bands in the original rock. Moreover, this softer material contains much of the dark dust and clastic chlorite characteristic of the horizon next above. The parallel-banded or passage-rocks are seen in part near Coldrach, and in the low ground between Glen

[1] See Pl. XXXVI, fig. 2 (No. 136).

Clunie and Glen Callater, continuing a short distance up the latter. Two other exposures occur in the neighbourhood: one in the nose and crest of the hill overlooking the junction of the two streams: the other along the crest of the southern face of the corrie behind Coldrach. It is easily seen that these passage-rocks, before they were folded, could not have been more than a few feet thick.

3. The Little Limestone.—The typical form of the Little Limestone, as seen in Glen Callater and Glen Clunie, is a remarkable rock, the origin of which becomes clear only after the bed next to it has been examined. The latter shows conclusively that the Little Limestone was originally an admixture of calcite, very finely-divided clastic chlorite, and marcasite, with possibly a small portion of carbonaceous material. When raised to a high temperature, an unusual combination of elements took place, resulting in the production of a glass-white hornblende (tremolite), in which lime and magnesia are mixed in equal parts, the iron-ore being rejected. The latter being dusted through the rock, which is essentially of massive habit, imparts to it an almost black colour, although the dominant constituent is glass-white. Occasionally yellowish films, mainly composed of epidote and zoisite, occur in it. In some cases there was slightly more lime than was necessary for the formation of the tremolite, and this is now scattered through the rock in small grains of crystallized calcite. The rock often bears a close resemblance to an epidiorite, and has to be carefully examined in order to place its identity beyond dispute. So long as the Dark Schist, to be described next, is of constant composition, the Little Limestone retains this aspect, and has been recognized as far away as the neighbourhood of Ben Vrackie, near Pitlochry; but, if the Dark Schist changes in composition, the Little Limestone changes too. The rock is met with in Glen Callater at the first small rapid above the bridge, though another and more interesting outcrop occurs at the sharp bend farther up, a little beyond the quarry, in the flaggy hornfels. The total number of outcrops in this neighbourhood is almost incredible, and shows conclusively the intense and complicated folding of the rocks.

4. The Dark Schist, with the 'twinned-chlorite-rock' and the 'felspar-rock.'—In a type-area, such as that south of Auchallater, where the Dark Schist attains its full development, it is characterized by the presence of an excessive amount of magnesian silicates, due to the existence in the original rock of an extraordinary quantity of finely-divided clastic chlorite. This material attained its maximum in the film of rock next the Little Limestone (the Twin-Chlorite Rock), and this is now seen in the form of abundant twinned crystals of chlorite. From this zone upwards, the clastic chloritic material steadily diminishes, on the whole, attaining its minimum close to the Main Limestone, where the most characteristic aluminous silicate is kyanite, or more rarely andalusite, containining no magnesia. As we descend,

staurolite appears, and twin-chlorite and other magnesian silicates steadily increase in amount. Where the metamorphism is more intense, the same phenomenon is shown by the greater abundance of cordierite in the lower part of this bed, while andalusite is more abundant in the upper.

Another characteristic of the zone a little above the Twin-Chlorite Rock, is the presence in large quantity of a felspar proved by Dr. Teall to be of the oligoclase-andesine group, containing curving lines of dark dust (the 'Felspar-Rock'). It occurs, to a small extent, through most of the bed, but appears to be abundant only towards the lower part. Its distribution seems to be the same as that of the tremolite-rock; the two, so to speak, go together, and have been recognized as far away as the neighbourhood of Druid Farm, north-west of Ben Vrackie (10,777). The dark dust that occurs in this felspar is met with throughout the whole of the Dark Schist in the Braemar area, but as a rule is most abundant about the Twin-Chlorite Rock. Here, a small portion of it is undoubtedly graphite, though, in most cases, very little of this material is of that nature. The dark dust seen under the microscope is often in part leucoxene, but by far the greater portion of it is iron-ore; its real origin was suggested by Mr. A. Dick's examination into the cause of the blue colour of unweathered London Clay. This proved to be the presence of a large number of minute spheroids of marcasite, and there can be little doubt that the dark dust of these rocks had a similar origin. The iron-ore in these rocks is slightly magnetic, and, if a specimen be ground to very fine powder, the greater part of the rock can be picked up with a magnet, owing to the even dissemination of the iron-ore throughout it.

5. The Main Limestone.—The typical Main, or Blair-Atholl Limestone, is well seen at the southern end of the corrie opposite Newbiggin in Glen Clunie, where it possesses the characteristic pale bluish-grey colour and crystalline aspect. The Clunie area shows well the tendency of the rock to become more impure as it approaches the belt along which the Moine Gneisses set in; or where there is a hiatus in the succession, and parts of the beds are missing. As a rule, however, only the basal portion is markedly impure, and as (in many cases) it is this part repeated by folding that is really seen, it gives the erroneous impression that the whole bed is impure.

6. The Calc-Flintas, or Parallel-Banded Calcareous Shales.—This bed consists of thin laminæ alternately richer and poorer in lime. The peculiarity from which it takes its name, is its more or less persistent flinty aspect, due to the presence of a variable number of bands composed of quartz, biotite, calcite, pyrites, and leucoxene. These originally contained much quartz and clastic chlorite in a fine state of subdivision, which, when heated, form a kind of hornfels at a specially-low temperature and this hornfels is so intensely hard, that it resisted shearing

movements anterior to the main crystallization of the Highland rocks.[1] Associated with the flinty bands are much paler, almost white, layers. The dominant constituents of these are white pyroxene and calcite. Other pale bands rich in epidote occur. All these phases may be found in the Calc-Flintas associated with the Main Limestone at the corrie opposite Newbiggin. They also show another feature of the rock: here and there special bands occur, differing in type from the normal. At this locality, a few bands have an almost micaceous aspect, owing to the presence of a great number of small parallel crystals, determined by Dr. Flett to be pale hornblende. The proportion of the more flinty material is small here, but the parallel banding is well shown. A very small infold of the pyroxene-bands is associated with the limestone in the bed of the Clunie at the southern end of Auchyndrine (Braemar).

(*f*) Further Evidence of the Succession.

It has already been shown that the Quartzite is succeeded by the Parallel-Banded Rocks; the best locality for ascertaining the nature and succession of the zones above the latter occurs in Glen Callater, at the bend of the stream above the quarry in the flaggy hornfels, above the bridge at Auchallater. At this bend, when the water is low, we see first the Little Limestone (tremolite-rock, 8091); next this comes the Twin-Chlorite Rock (8092) of a characteristic dead-black, due to the presence of graphite; while next this again come the various portions of the Felspar-Rock (8094, etc.), often known as the Felspar-Hornfels[2] of Glen Callater. At the southern edge of the quarry (see map, fig. 4, p. 422), in the flaggy hornfels, we see again the Felspar-Rock, with its glistening crystals of felspar rendered dark by the presence of the dark dust, which serves to fix the horizon of the rocks within the quarry. These are characterized by a flaggy habit, the splitting-faces being coated with bronzy mica and, at times, with small spots. The different bands vary in colour and compactness. The darkest have a somewhat flinty cross-fracture, and contain a great quantity of fresh andalusite showing the typical pink pleochroism. Except on the splitting-face the amount of biotite present is small, but there is a considerable quantity of shimmer-aggregate material replacing some alumina-silicate. Quartz is subordinate in amount, and a small quantity of felspar is present. The typical dark dust is abundant, and the structure of the rock is essentially that of a hornfels. A band, in which the flinty cross-

[1] The hornfels-like aspect of this rock, traceable over half the breadth of Scotland, is due to the fact that, after induration, it usually escaped crushing owing to the plasticity of limestone at a high temperature (as proved by the experiments of Prof. Adams & Dr. Nicolson). The limestone next the flintas gave way readily and relieved the latter from the crushing stresses. Many other rocks must have been similarly indurated, but possessing no such yielding margin they have been since crushed.

[2] See § IV, p. 442, at the end of which the bearing of this rock on the absence of metamorphism due to the neighbouring mass of granite is discussed.

fracture is not so marked, contains less andalusite but far more shimmer-aggregate material. The most micaceous part of the rock, with numerous spots on the splitting surface, shows marked parallel structure under the microscope, and is composed of abundant pale biotite associated with quartz, a little felspar, and some andalusite. The elongated micas sweep round small patches in which no parallel structure is seen, and these are probably eyes of material that have been indurated anterior to the main crystallization of the mass, and have thus escaped crushing.

Now, the rock so rich in andalusite is seen again close to the Main Limestone, both at the head of the corrie about a mile to the north-north-east of Auchallater, and 2 miles to the south-south-west, in the corrie opposite Newbiggin. It is thus clear that there is not much more rock present in the whole of the Black Schist than the few bands above described, and it cannot have been much more than 15 feet thick originally. This will be understood by following up Glen-Callater Burn as far as the ford; there, except the granite, nothing is seen but the Felspar-Rock and the closely-adjacent material, repeated incessantly by folding. A difficulty arises from the different phases of metamorphism; for, when the material was considerably heated anterior to the main metamorphism and indurated so as to escape subsequent crushing, it is found, in this area, finally to crystallize as an andalusite-hornfels; but generally, if much crushed, it finally assumes the form of a kyanite-schist. In both cases, it will be noted that it is a non-magnesian silicate that is so abundantly developed in the highest band. In some cases, the andalusite appears as a number of minute laths that in their mode of occurrence simulate kyanite, and in other localities are replaced by kyanite. This gradual diminution in the amount of clastic chlorite present in the original shales has been noted over a wide area, and suggests continuous deposition or an unbroken sequence from the Little Limestone to the rock rich in kyanite or andalusite next the Main Limestone.

For the purpose of building up the sequence the most valuable evidence, however, is obtained from the association of the Main Limestone with the Calc-Flintas, or altered, parallel-banded, calcareous shales. The accumulated experience of years of detailed mapping makes it certain that in these two rocks we have a record of continuous deposition, or a portion of an original and unbroken sequence: no other bed in the series can intervene between them, and in any account of the succession they must always be taken together. Again, experience has shown that, with very rare exceptions, the calcareous shales always overlie or succeed the main bed of Limestone. Now these Calc-Flintas occur in most of the broader valleys over a very large area, especially where the beds between the Quartzite and the Main Limestone are wholly missing. It must be remembered that in the former case it is not merely the original thickness of the beds that is missing, but the great mass of rock built up by their intense folding; a large gap is consequently left

to be filled up by the folded higher beds. This happens along almost the whole length of the south-eastern side of the Ben-y-Ghloe Mountains, which rise from comparatively low ground to a height of more than 3600 feet above sea-level. The gap to be filled up is exceptionally large, and in consequence the largest known outcrop of the Calc-Flintas occurs here, and we see in addition a small number of thin infolds of the altered dark shale originally above the Calc-Flintas. But over the whole of the rest of the country, the rock on the reverse side of the flintas to the Main Limestone is never seen; and the flintas must in all other cases be either the highest or lowest rocks in this part of the South-Eastern Highlands, and the evidence is conclusive that they are the highest.

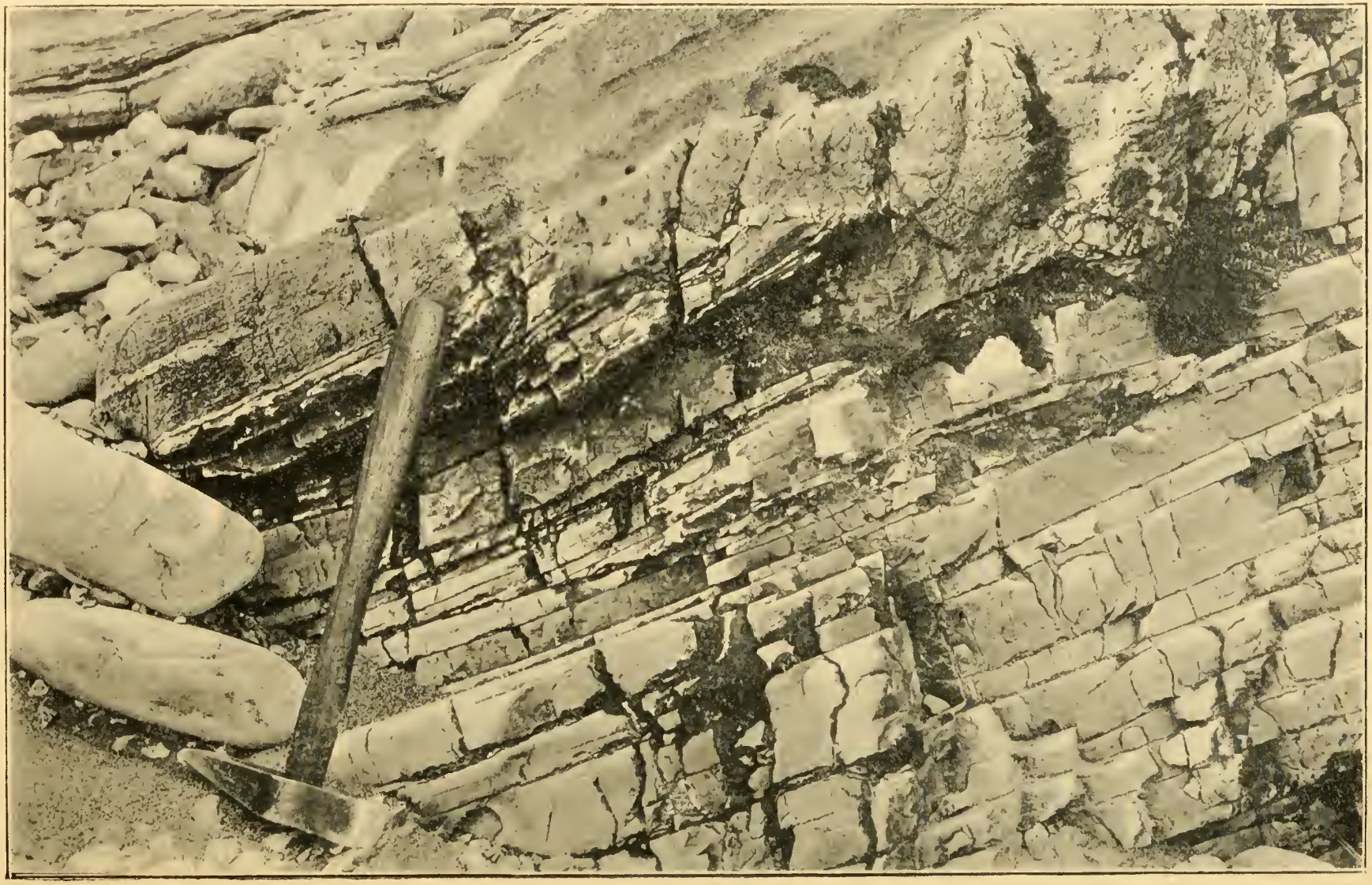
This view, that there is a descending succession from the Main Limestone to the Quartzite, is greatly strengthened by the frequency with which a hiatus occurs at the margin of the Main Limestone, a good example of which is shown on the map (fig. 4, p. 422) in the corrie opposite Newbiggin. Sometimes the whole of the Dark Schist and the Little Limestone are missing, sometimes portions only; but as the investigation proceeds, it will be seen that the line of erosion at the base of the Main Limestone is not by itself sufficient to explain all the phenomena met with.

(*g*) Meaning of the Patches of Dark Schist and Proof that the Sequence is incomplete in the Glen-Tilt Area.

The meaning of the patches of Dark Schist in the Gilbert's-Bridge and Banvie-Burn sections can now be investigated.[1] Below Gilbert's Bridge, close to Crombie Burn, one of these patches intervening between the limestone and the Moine Gneiss is a kyanite-garnet-staurolite-schist, obviously well above the bottom of the dark shale, but almost certainly a little below the top. There are several other small patches below Gilbert's Bridge, and these appear to be approximately at the same horizon. Nearer Gilbert's Bridge a film of tough schist occurs between the Limestone and the Pink Felspathic Rock. This (10,549) is a highly-micaceous rock, built up of alternating films of quartzose and micaceous material; the latter consist largely of white mica and chlorite, often enveloping large cracked and decomposed garnets. Iron-ore is abundant, both in good-sized grains and as fine dust, and it is often embedded in a clear, almost glassy material, which is known to be plagioclase although it here shows no striation. There can be little doubt that this is a siliceous modification of the Felspar-Rock, and it illustrates a difficulty that occurs repeatedly. As the area is approached where the more sandy material, now forming the Moine Gneisses, was deposited, the Dark Schist tends to become slightly more siliceous, and differs slightly in appearance from the rocks of the type-area. If the siliceous material increases beyond a certain point, the zone can, of course, be no longer identified. So far as is

[1] See Map, Pl. XXXIII.

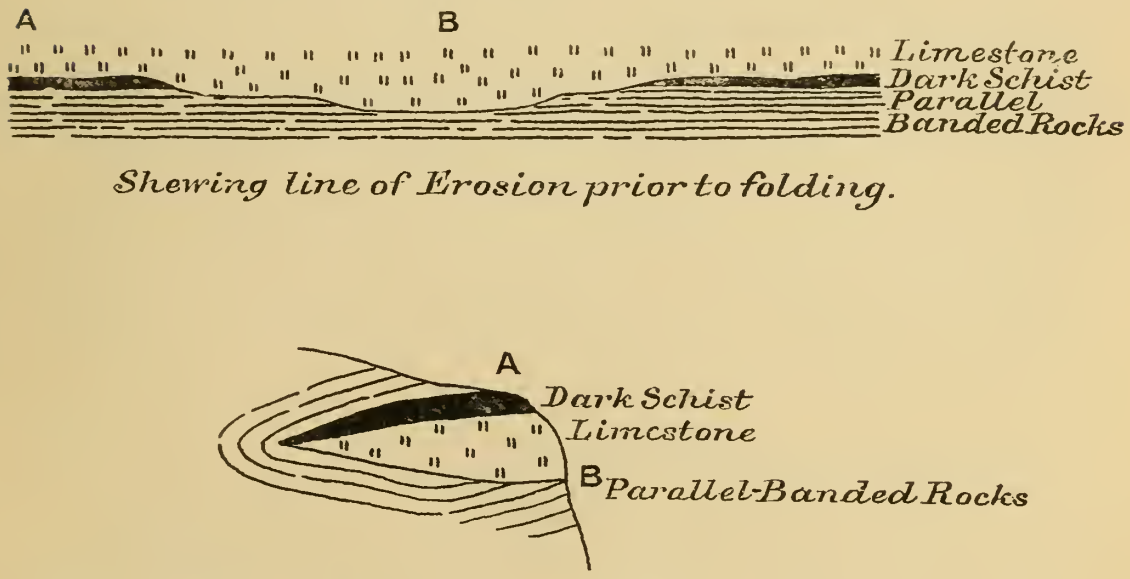
Fig. 5.—*Line of erosion in fine Moine Gneisses at the base of the Main Limestone : Glen Tilt, below Marble Lodge. (The spot is denoted by an asterisk * on the map, Pl. XXXIII.)*



known at present, this increase is more marked in the lower part of the Schist than in the upper.

Of all these patches of Dark Schist, the most interesting is that which lies apparently on the top of the Limestone in the river-bank at the first bend below Marble Lodge. (See fig. 5, p. 430.) Here the Limestone is shown resting in an eroded hollow of the attenuated Parallel-Banded Rocks into which the Moine Gneisses have slowly passed, while lying apparently above the Limestone is the patch of Dark Schist now mentioned. It is a dark, somewhat massive rock, evidently rich in biotite, but containing a number of very minute lenticular films of quartz, suggesting that, as we approach an area of more sandy deposition, the Dark Schist

Fig. 6.—*Diagram showing the Dark Schist and Parallel-Banded Rocks apparently on opposite sides of the Limestone, while in reality they are on the same side.*



has become more quartzose (10,421). The rock contains much granulitic quartz, which represents the minute lenticles referred to, and a great quantity of more or less aggregated crystals of red biotite; the typical felspar with much dark dust, like the Glen-Callater hornfels, is abundant, and there is one crystal of andalusite. It is clearly a slightly-siliceous phase of the upper part of the Felspar-Rock. The occurrence of the Felspar-Rock above a thin band of Limestone, with the Parallel-Banded Rocks below it, seems, at first, conclusive evidence that the limestone must be the Little Limestone. In reality it is an ideal example of the kind of deception so often produced by folding of a slightly-vague succession in the Central Highlands. If we consider carefully the meaning of the sporadic occurrence of lenticular patches of Dark Schist below Gilbert's Bridge, it becomes obvious that the folding may so involve one of

these patches, as to make it appear that it is on the opposite side of the Limestone to the Parallel-Banded Rocks, while, in reality, it is on the same side. The foregoing diagram (fig. 6, p. 431) shows clearly both the deceptive structure and its explanation.

Similar patches of dark schist occur in Glen Banvie, and of these the most interesting lies next the small mass of hornblende-schist 100 yards above the lower bridge, in the Whim Plantation. It consists of two parts: one very dark, with a dead-black film, and a fine grey siliceous schist or granulite. Three microscope-slides were made of the dark portion (10,551–10,553), and these show that part of the rock contains much dark dust, rich red biotite, while epidote and zoisite are abundant along certain lines in an adjacent portion. Another is tougher and darker, intensely chloritic, containing decomposed garnets and a little andalusite; a third is composed of felted white mica and pale chlorite. The dead-blackness of part of this rock, along with the occurrence of epidote and zoisite along certain lines, suggest that we may have here a representative, though very thin, of the Little Limestone; for the Little Limestone will be shown later to pass into an epidote-zoisite rock, containing much dark dust, before its outcrop is finally lost. It is the only known occurrence of this dead-black material within a short distance of the actual Moine Gneisses. The rock next it is very fine in grain, and composed of white and dark mica arranged parallel in a fine granular matrix of quartz and felspar. It can be very closely matched from the Honestones and, by its texture, shows how rapidly the rocks become finer in grain as we cross the belt of decreasing crystallization.

The examination of these patches of schist clearly shows that they belong to different horizons; not only is there a hiatus at the base of the Main Limestone, but there is also liable to be one at the top of the Moine Gneisses, or the Parallel-Banded Rocks into which they pass. It seems as though, in an area where the originally-coarser material of the Moine Gneisses was deposited, the currents were strong enough, either to prevent the deposition of the fine mud, or to wash it away after it was deposited. Owing to the shifting nature of the currents, patches of the fine mud were, however, left, and these lie at different horizons. The finest material of all was probably that which formed the Little Limestone and the Twin-Chlorite Rock, and this is the portion of the sequence that is most persistently missing. But, as already stated, the total thickness of the Dark Schist was quite small, and the hiatus is of no great consequence. In connection with it, however, we note a remarkable fact: it is succeeded by a limestone, very impure and very variable in composition. Now, at the top of the Upper Lias in East Yorkshire a similar sifting-away of the fine mud took place, followed by the deposition of a very impure and very variable limestone, now altered to ironstone, the Dogger or base of the Lower Oolites. Proceeding in one direction, the succession beneath this impure limestone becomes complete at Blea Wyke, on the coast south of Robin Hood's Bay. Proceeding in the opposite direction—inland—

the sifting-away occasionally takes a stronger form, and large holes were dug in the soft dark mud, one of which occurs at Bilsdale (nearly 100 feet deep), the other near Rosedale Abbey; in both cases, the eroded hollow was filled up with impure limestone.

No further evidence, bearing on this investigation, is met with till the northern end of the long straight portion of the Tilt Valley is reached. Here, just above the junction with the An Lochan, a section occurs closely resembling that at the sharp bend in the Tilt at Crombie Wood, below Gilbert's Bridge: the Pink Felspathic material being again present. Ascending the river-bed from this point, when the stream is low, the Honestones can be seen to pass gradually into fine Moine Gneisses. This part of the river is somewhat obscured by numerous small protrusions from the Glen-Tilt complex; but the passage can be well seen a little above Pool Tarf, along the bed of the Tilt, and in the first small stream south of the Tarf. Here, the passage of the Honestones into the Moine Gneisses is practically unbroken. This is due to the lucky accident that only the less markedly-siliceous part of the Honestones is present; a single infold of the more markedly-siliceous portion would have broken the continuity of a gradual change.

On looking at the map, the reason why this gradual change can be traced becomes at once obvious. As in the Gilbert's-Bridge section, the Tilt once more makes a large bow. As before, one end of the bow lies at one side of the belt of decreasing alteration, the other almost at the opposite side; it does not quite do so, and this is why, in addition, the small burn has to be ascended in order to see the full change.

(*h*) The Falar Area.

Considerable light is thrown on the present investigation by the clear, continuous sections in the deep gorges that characterize the Falar portion of the Tilt drainage-area. The most convenient starting-point lies at the junction of a little burn with Glen Mohr, immediately north of Glen Bheag. In the lower part of the little burn, the small sill of hornblende-schist and part of the Dark Schist are exposed, repeated several times by folding. In the bed of the main stream below, is an excellent section of the Honestones with the Little Limestone next them, and beyond this a high bank composed of the Dark Schist. The locality was often visited in former years by farmers and shepherds, who came from considerable distances to procure a certain portion of the parallel-banded material to be used as honestones, and it is to this fact that the beds owe their distinctive name. These Honestones are characterized by their even colour-banding, and are composed of a number of alternating softer and harder layers, most of which contain a considerable amount of biotite, arranged parallel to the banding or bedding. The portion of the rock nearest the Little Limestone is, on the whole, the softest; and it at first contained most clastic chlorite. This often occurred in little felted films, obviously identical originally with the

felted biotite-films in the Moine Gneisses, and along which the rock readily splits. Close to the Quartzite, a few far more siliceous pink and white bands occur, and in these muscovite is more abundant and there is less biotite. The intermediate portion is a thinly-banded, fine-grained, brown or grey rock, obviously containing a great deal of fine brown mica. This is the dominant constituent of the group, and in a typical example (9797) the more siliceous bands are composed of a singularly-even admixture of quartz-grains and minute flakes of biotite, with, possibly, some water-clear felspar; the structure is essentially that of a fine biotite-granulite. The more micaceous portion contains far less quartz or felspar, and is largely composed of finely-felted brown mica, with which some larger crystals of muscovite are associated, set athwart the foliation as in a spangled gneiss. These micaceous films are peculiarly interesting, for they have been met with over a large area, among others, on the north-west side of Ben Vuroch.[1]

The Little Limestone, though still containing the typical dark dust, differs from the tremolite-rock in the fact that the bulk of the hornblende is now actinolite. A still more important difference occurs in the schist forming the steep bank above the stream. It is lighter in colour than the typical Dark Schist, and a series of sections shows that it originally contained far less clastic chlorite and fine dark dust; still, the maximum amount of chlorite occurs in the portion of the bed next the Little Limestone (9794, 9792, 9795, 9790). It is thus seen that, although we have here the full sequence of the beds about the Little Limestone, each band differs slightly in composition from the type-rocks of the section about Auchallater. It places the true position of the Honestones, however, beyond dispute, and is especially important because it will be seen immediately that this is, so to speak, the most siliceous phase in which the Honestones are ever known to occur in this area accompanied by the full sequence. So soon as they become markedly more siliceous, the Little Limestone and part of the Dark Schist appear to be almost always missing in the area here described.

This fact can be seen at once by ascending Glen Mohr. A little above the junction with Glen Bheag, the stream flows along the strike of the rocks. In the bank on one side we have the repeatedly-folded margin of the Limestone, on the other the white edge of the Quartzite: the bed of the stream being formed by the Honestones, now somewhat more siliceous, but still unmistakable. In quite a short distance, the Honestones pass into a small group of quartzite-bands, with a patch in the centre in which the honestone-character is still traceable. Of these quartzite-bands, the one nearest the limestone is quite white and almost indistinguishable from the margin of the Quartzite; the other bands are pink and grey. When the ground was first examined, the limestone was taken for the Little Limestone; for it appears to be very thin, has a bright pink colour, and is exactly in the position where the Little Limestone should be. The recent traverses, however, make it more probable

[1] See explanation of the Geological Survey 1-inch map, Sheet 55 (Scotland).

that it is the base of the Main Limestone, which has here undergone one of the startling changes in appearance so often noted; for quite close by, and over much of the Falar area, the Main Limestone has the appearance of the normal rock of Blair Atholl.

This change of the Honestones into a series of quartzite-bands of variable colour is highly important for two reasons. In the first place, it is obvious that these are the bands that, repeated incessantly by folding, form the Moine Gneisses along the Sluggan Road in Invercauld Forest, already described (see p. 413): the highest white band, in particular, is especially important, for it forms the top of the Moine Gneisses below Gilbert's Bridge and in many other localities. The second point is that a change in composition, similar to that along the main line where the Moine Gneisses begin, is now taking place in a south-easterly instead of a north-westerly direction; in other words, the change in composition of the rocks, due to powerful current-actions accompanied by the deposition of more siliceous material, is repeated to the south-east. The survey of the whole area has shown that this tendency to revert to more sandy conditions of deposition occurs again and again south-east of the Moine Gneiss area and, though carried to a far smaller extent, it is almost invariably accompanied by the silting-away or non-deposition of the finer clastic material.

Below the type-section in Glen Mohr, the Honestones are often exposed in the bed and sides of the gorge. A little above Falar Burn they have an almost flinty aspect, and are characterized by even banding, recalling a very fine phase of the Moine Gneiss (11,125). Structurally, the rock is a very fine quartz-biotite-granulite, but its most striking feature is the arrangement of the crystals of brown mica. Though rigidly parallel, they are oblique to the bedding, which is clearly seen under the microscope. Just at the mouth of Falar Burn there is a distinct increase in the amount of originally-softer material present, and a type-specimen (9453) could be matched from the mouth of Glen Callater. Near the foot of Glen Mohr the whole of this softer material has disappeared, and now only a thin film of the more quartzose pink-and-grey material separates the Main Limestone from the Quartzite. It is obvious that there is a slight line of erosion at the base of the Limestone, showing that it must be above the Quartzite. The pink-and-grey material (9406) is singularly like a portion of the Moine Gneiss, except that it is finer in grain; and the resemblance is equally marked in a microscopic section.

(*i*) The Aberdeenshire Area.

Turning now to the Aberdeenshire area, and following these finer Parallel-Banded Rocks in a direction parallel to that along which the coarser Moine Gneisses have been traced, an interesting outcrop occurs about half a mile up Allt-na-Bronn, to the east of the Bynack. Here the quartzite is succeeded by a thin series, composed of

alternations of yellow or grey quartzose laminæ and films of dark material, the whole bearing an unusual resemblance to unaltered sediments (8522, 8523, & 8524). The grey siliceous laminæ closely resemble the typical Honestones from Glen Mohr, but as a whole they are intermediate in composition between these and the parallel-banded rocks at Glen Callater; indeed, 8524 can be exactly matched at Glen Callater. Similar material occurs in several instances in this neighbourhood next the Quartzite, and at the head of Glen Chonnie it is succeeded by the Little Limestone (8549). The latter shows well the change that takes place as the Parallel-Banded Rocks become more siliceous or the dark partings become thinner. In place of being built up mainly of white hornblende, the Limestone is now composed of aggregated patches or crystals of this mineral set in a matrix of calcite, biotite, quartz, and iron-ores. The fine dark dust is present in smaller quantity. In this part of the district the Limestone always loses its typical aspect as the border of the Moine Gneisses is approached, and in one case resembles a film rich in epidote noted in the Banvie Burn (8551, 8552).

The Parallel-Banded material just described is obviously the equivalent of the more micaceous portion of the Honestones. In the next burn to the north (Allt Unich), the more siliceous pink-and-grey material next the Quartzite is more persistently exposed. Starting where the two branches of the burn join, the Quartzite and the marginal rocks (Honestones) are well shown, the latter being clearly the same as No. 9406 from the foot of Glen Mohr. These rocks were obviously part of one bed of sandstone originally, and they now fold together as one rock, and are quite inseparable. Farther down the stream they not only become more crystalline, but the pink-and-grey portion rapidly thickens. The burn is obscured by Drift for a short distance, but fortunately the rocks can be followed in the bank to the south-west; and, returning to the burn once more, just before the fault is reached we find the coloured bands now so highly crystalline that a specimen (8518) taken from a little scar at the burn-side is a typical pink-edged epidotic gneiss, practically identical with No. 8519 taken 7 miles away from the heart of the Moine-Gneiss area, and close to the margin of the Cairngorm Granite. It will be noted that, in this little scar, the low dip of the Moine Gneiss and its accompanying structures are met with. To the north-east of this point, towards Braemar and well up the hill-side, it is evident that the Quartzite is also involved in the movements that produced the Moine-Gneiss structure; and this is placed beyond dispute by the distinctive pink-and-grey colour of the marginal rock. From this burn, then, almost to Braemar, a large portion of the Moine Gneisses are really the Quartzite, in what may be conveniently called a 'Moine-phase.'

At the northern foot of Morone, rather more than 2 miles south-west of Braemar, the Limestone and Parallel-Banded Rocks are exposed in the face of a small scar. In this, the margin of the Limestone is repeatedly folded on itself, and has almost the typical

low dip characteristic of the Moine Gneisses in this area. Close to, or in contact with it, is the more micaceous portion of the Honestones, which are here thicker and so markedly crystalline that it is questionable whether they are to be called Honestones or Moine Gneisses. They contain much biotite, and the characteristic original films of chloritic material now largely altered to biotite. These obviously represent the softer, or more micaceous portion of the typical Honestones that are farthest from the margin of the Quartzite. The portion closer to the Quartzite forms the lower hill above the road and is a highly-quartzose, more or less banded gneiss. The flat ground at the foot of the scar between the two types of rock is unfortunately obscured by Drift, and their relation to one another is not at first clear. Briefly put, the doubtful Honestones, or softer bands, are a little way within the belt of increasing crystallization, but not sufficiently far to give them a decisive character; the more quartzose gneisses farther down the hill are well within the belt, and their character is unmistakable.

At this locality, the Pink Felspathic material of the Gilbert's-Bridge area is again intimately associated with the Limestone and, to a smaller extent, with the adjacent rocks; the most important constituent of this pink material is again microcline. Further, the softer rocks close to the Limestone are identical with the more crystalline portions of the Honestones below Pool Tarf in the Tilt, where, as previously stated, the further passage to Moine Gneiss is practically unbroken.

We may conclude this account of the mode of ending-off of the Moine Gneisses with a brief description of three sections, in all of which the horizon of the Parallel-Banded material can be fixed just before it becomes too thin to be shown on a map.

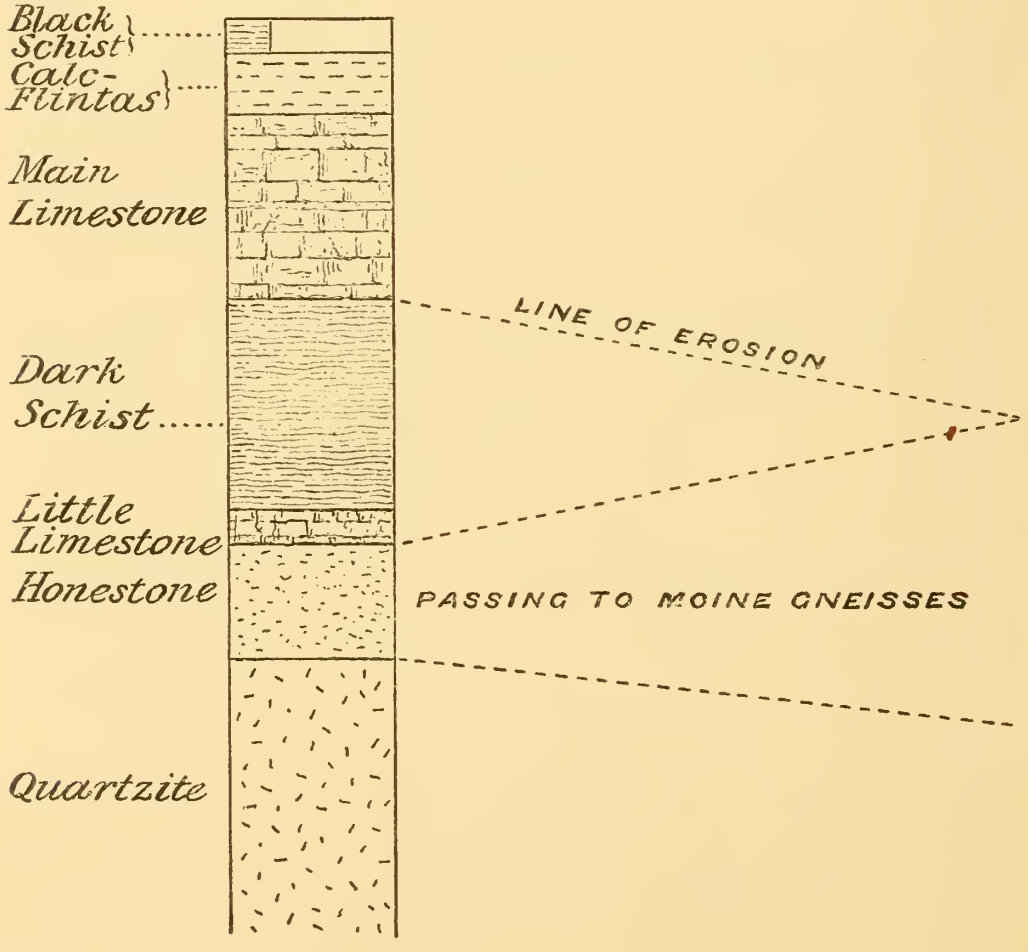
The first occurs about the hill of Creag-na-Dala Bige, in the Invercauld Forest, overlooking the head of the Cairn. To the west of this hill the Moine Gneisses cover a considerable area, although this is largely composed of a single folded band, characterized by pink edges and containing much epidote, already referred to. The gneiss is succeeded to the east by a considerable mass of well-foliated Dark Schist, here highly crystalline and containing some sillimanite, and so much cordierite as to show that it was highly chloritic originally, and is the lower part of the bed (8435). A few small infolds of the Main Limestone occur within this Dark Schist. On the opposite or eastern side of the Dark Schist, the Moine Gneisses are represented by a small thickness of faintly-banded quartzose rock, quite inseparable from the main Quartzite seen a little farther down the hill.

The second occurs on the hill above Balloch, about a mile and a half east-north-east of Invercauld House, and has been already referred to (p. 414). The thin, faintly-banded, highly-quartzose representative of the Moine Gneisses is here succeeded directly by the Main Limestone (9825); and there is clearly a slightly-larger hiatus than at the locality just mentioned. A little farther west, the Parallel-

Banded material is seen in the scars to have thinned away, and to be no longer separable on a map. In this direction the Dark Schist slowly thickens, until in a few places the full sequence may be seen.

The third section occurs about 3 miles to the south-east of Balmoral, on the ridge north-west of Girnoch Burn. Here the Main Limestone (9828) is often separated from the Quartzite by quite a thin parting of dark siliceous schist, which locally thickens to a flinty Parallel-Banded rock (9816), resembling the specimen 11,125 of the Honestones from Glen Mohr. It is, however, still more like a flinty biotite-schist that occurs repeatedly in the corrie behind Coldrach in Glen Clunie, but is there in contact with the Little Limestone. The extent of the hiatus at the Girnoch ridge is thus clearly defined; the whole of the Dark Schist and the Little Limestone is missing, and this is exactly the hiatus with which we started, at Gilbert's Bridge, 30 miles away.

Fig. 7.—*Diagram showing the true succession of the rocks described.*



From the evidence adduced, it will be seen that along a line more than 30 miles long the Moine Gneisses, when traced to the south-east, tend both to thin away and to pass into a material which was originally of a more muddy nature. Along a considerable portion of this line, the change is accompanied by a rapid decrease in

crystallization; and this materially increases the difficulty of ascertaining the mode of ending-off of the recognizable gneisses. When an area of more sandy deposition is approached, there is always a tendency for a hiatus to occur in the sequence, the Little Limestone and part of the Dark Schist being almost always missing. Moreover, the Dark Schist itself tends to become more siliceous and to contain less dark dust. A similar change undoubtedly occurs in the Little Limestone before it disappears; but the bed is so thin that it is often difficult to find, and its exact mode of ending-off has not been satisfactorily determined. The hiatus is most frequently noticed at the base of the Main Limestone, which is clearly above the Dark Schist and the Moine Gneisses. But the missing beds were originally of no great thickness, and are only those that lie between the base of the Limestone and the Parallel-Banded rocks, except where the latter were originally composed of comparatively-fine mud. Over the whole belt of ground examined, more than 30 miles long, this hiatus never exceeds these limits, clearly showing that it cannot be claimed as an important stratigraphical break in the sequence of which the Moine Gneisses form a part. Where no hiatus at all occurs, the Parallel-Banded rocks are succeeded by the Little Limestone; and the true stratigraphical position of the Moine Gneisses is thus defined, as lying between the Little Limestone and the white edge of the Quartzite, of which, indeed, they are simply the flaggy top. The succession in the group of rocks described and their mutual relations are briefly expressed in the appended diagram (fig. 7, p. 438).

(*k*) Horizon of the Gneisses north-west of the Belt along which they thin away.

When well across the line of thinning-away, the upper limit of these gneisses can often be fixed; and a few type-localities may be selected for this purpose. One of the best lies about Derry Lodge, where both the Limestone and the Dark Schist are present. Close to the Derry Falls the Moine Gneisses are succeeded by a small portion of the Dark Schist; but this is so much more quartzose, and contains so little dark dust, that it is practically impossible to fix its exact horizon (10,882), although the occurrence of the Main Limestone next to it shows that this must be a representative of part of the Dark Schist. A small quantity of the typical felspar is present; and the rock possesses the flaser-structure so characteristic of the Highland metamorphism. Some distance to the south-east of Derry Lodge, a rather similar section occurs; but here the Limestone is associated with the Pink Felspathic material once more (8274).

Even when no limestone is present, the upper limit of the gneisses can be approximately fixed by the presence of identifiable portions of the Dark Schist. Two good illustrations of this occur in the Tarf Valley. On the south side of the stream the infold is

too large to leave any doubt as to its horizon; but on the north side the infolds, which occur at the south-western foot of Sron na Macranach, are so small that they can be identified only by the aid of microscopic sections. One of these (11,137) is substantially identical with another (11,136), taken from the south-west of the Glen-Tilt complex, and lying between the Limestone and the Quartzite. Both lie well across the belt of increasing crystallization, and both contain a small quantity of sillimanite

The evidence thus shows that here and there small patches or infolds of Dark Schist and of the Main Limestone may be found within the main area of the Moine Gneisses; but, as previously explained, there is now a tendency for the Dark Schist to become more siliceous and to contain less dark dust, so that it is difficult to identify. But, by first studying the more siliceous phases where the Main Limestone is present to fix their position, such as those seen at Derry Lodge, the true horizon and meaning of these infolds become clear.

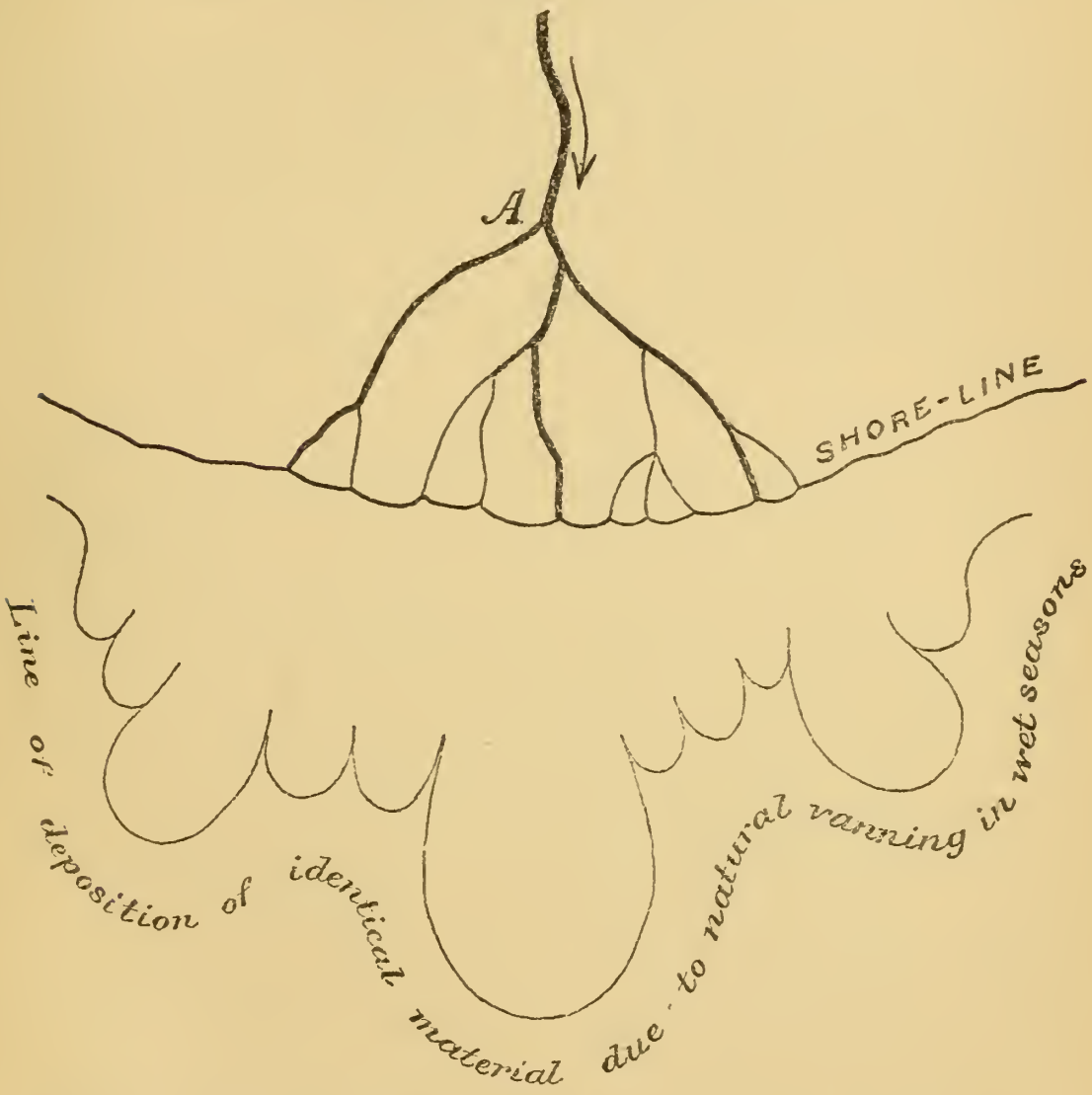
Attention has already been drawn to the fact that a great deal of the most highly-quartzose Moine Gneiss is simply the Central-Highland Quartzite in a Moine-phase; and if this, as well as the infolds just referred to, be deducted from the areas in which the Parallel-Banded rocks occur, it is soon seen that the true Moine Gneisses need have had no great thickness originally. The evidence of the incessant recurrence of some easily-recognized small band in a typical area strongly supports this idea.

(*l*) Slight Reversions to Similar Conditions of Deposition.

Attention was drawn to the fact that in Glen Mohr a change in composition in the Honestones takes place in a south-easterly direction, on similar lines to that seen in a north-westerly, as the main area of Moine Gneiss is approached. But the change is more local, and not carried to the same extent. In Glen Ey, also, the Honestones become locally more siliceous and, moreover, are occasionally mingled with the Pink Felspathic material, evenly disseminated through them. Similar small local changes occur in other areas; and an excellent example occurs in Glen Loch, in the upper part of Glen Firnate, in Perthshire. Here, on the margin of the Quartzite, a thin band of material occurs (3838, 3839), practically identical with that seen in the less-altered rocks of the Unich section (Pl. XXXVII, fig. 2, No. 150). These small reversions are of considerable importance, as they afford the key to the phenomena of the distribution of the Parallel-Banded material. This distribution has resulted from the natural vanning of the detrital material brought down by a large river with many mouths, of widely-different sizes, but all tapping a common source at A (see fig. 8, p. 441). There must be a series of points in front of these streams, at which clastic material of a definite

texture and composition will be deposited, provided local currents do not intervene. By joining up these points, we obtain the line shown in the diagram. In this investigation the line

Fig. 8.—*Diagram to illustrate the mode of arrangement of the areas in which the typical flaggy Moine Gneisses now occur, and also the origin of the film-partings, now rich in felted biotite, to which the flaggy aspect of the gneisses is essentially due.*



[For convenience of illustration, it is assumed that the distribution of the detritus brought down is not interfered with by other local currents. This interference would, of course, occur, and has doubtless added to the difficulty encountered in unravelling the meaning of the distribution of the Moine Gneisses.]

may be taken as defining the fans of the more sandy material from which the Moine Gneisses have been formed. The typical areas are the larger fans; the instances of slight reversion to similar conditions of deposition lie within the smaller ones. In addition, the origin of the fine films of chloritic material now

becomes clear. While the coarser material is deposited within these fans in wet periods, in dry the line of deposition of finer material would penetrate far within the fans (or towards the shore-line), and thus the coarser material within them would be separated by these films at more or less regular intervals. The origin of the flaggy aspect of the typical colour-banded gneisses is thus accounted for. In this investigation we have been dealing with the phenomena along the margin of one of the larger fans; but the identity of the Moine Gneisses over large areas makes it clear that there must be several larger fans.

Briefly, then, the Moine Gneisses are simply the flaggy top of the Central-Highland Quartzite: this flaggy top is restricted to certain larger fans of deposition. As we approach the margin of each fan, the flaggy material becomes of a more muddy nature originally; and while the typical parallel banding is retained, it becomes very much finer and the whole bed thinner. It is to the fact that this change in original composition has not been hitherto quite fully grasped, that the difficulty in accounting for the disappearance of the gneisses is essentially due.

IV. Appendix.

A peculiar interest attaches to the easily-identified phases of the Felspar-Rock of Glen Callater, as by means of them it can be proved that the great masses of newer granite, shown on a geological map of this area, have rarely produced any serious effect on the already-metamorphosed Highland rocks. The following series of slides (as well as a number of others) was cut so as to put this fact beyond dispute, as well as to identify the zone in the Dark Schist.

10,777. Quarter of a mile north of Druid Farm, above Killiecrankie, and north-west of Ben Vrackie. Perth; 1-inch-sheet 55.

9454. Near the head of the Tilt, north of Falar. Perth; Sheet 64.

8548. Near the head of Glen Choinnich, one of the branches of the Ey Burn. A branch of the Dee above Braemar. Aberdeen; Sheet 64.

10,778. Glen Ey, below Aucherric. Aberdeen; Sheet 65.

3455. Glen Callater, just outside the Lochnagar Granite. South of Braemar. Aberdeen; Sheet 65.

7975. A small patch of Dark Schist, completely enveloped in the Lochnagar Granite. Close to the last.

The Lochnagar Granite is 10 miles in diameter, yet this inclusion of the Felspar-Rock does not appreciably differ from any of the others. The first specimen was taken 25 miles from this inclusion, and there is no newer granite anywhere near it. Thus it is evident that the great mass of the Lochnagar intrusion has produced practically no effect on the already-altered Highland rocks. All these specimens have been taken from the south side of the great belt of increasing metamorphism.

On the north side of the belt similar phenomena are observed. Here the original chloritic material is absorbed in the formation of cordierite, but if the right portion of the Dark Schist be selected,

the felspar with the dark dust is still seen to be present. A good illustration of the failure of the newer intrusions to affect the Highland metamorphism is afforded by the two specimens (11,137 and 11,136) selected to fix the upper limit of the Moine Gneiss. The first is a small infold on the north side of the Tarf, and a considerable distance from any granite. The second was taken near the margin of the Glen-Tilt diorite, and forming really part of its thin roof. The metamorphism of the two is substantially identical; indeed, it is not easy to obtain two rocks, so far apart, which have so nearly the same composition, and show so exactly the same metamorphism.

The published Geological Survey-Maps of Scotland (sheets 66 & 67) equally show that the course of the great 'sillimanite-aureole' is entirely unaffected by the Kincardineshire granite, for the aureole meets the margin of the intrusion at right angles on its eastern side.

Explanation of Maps and Section.

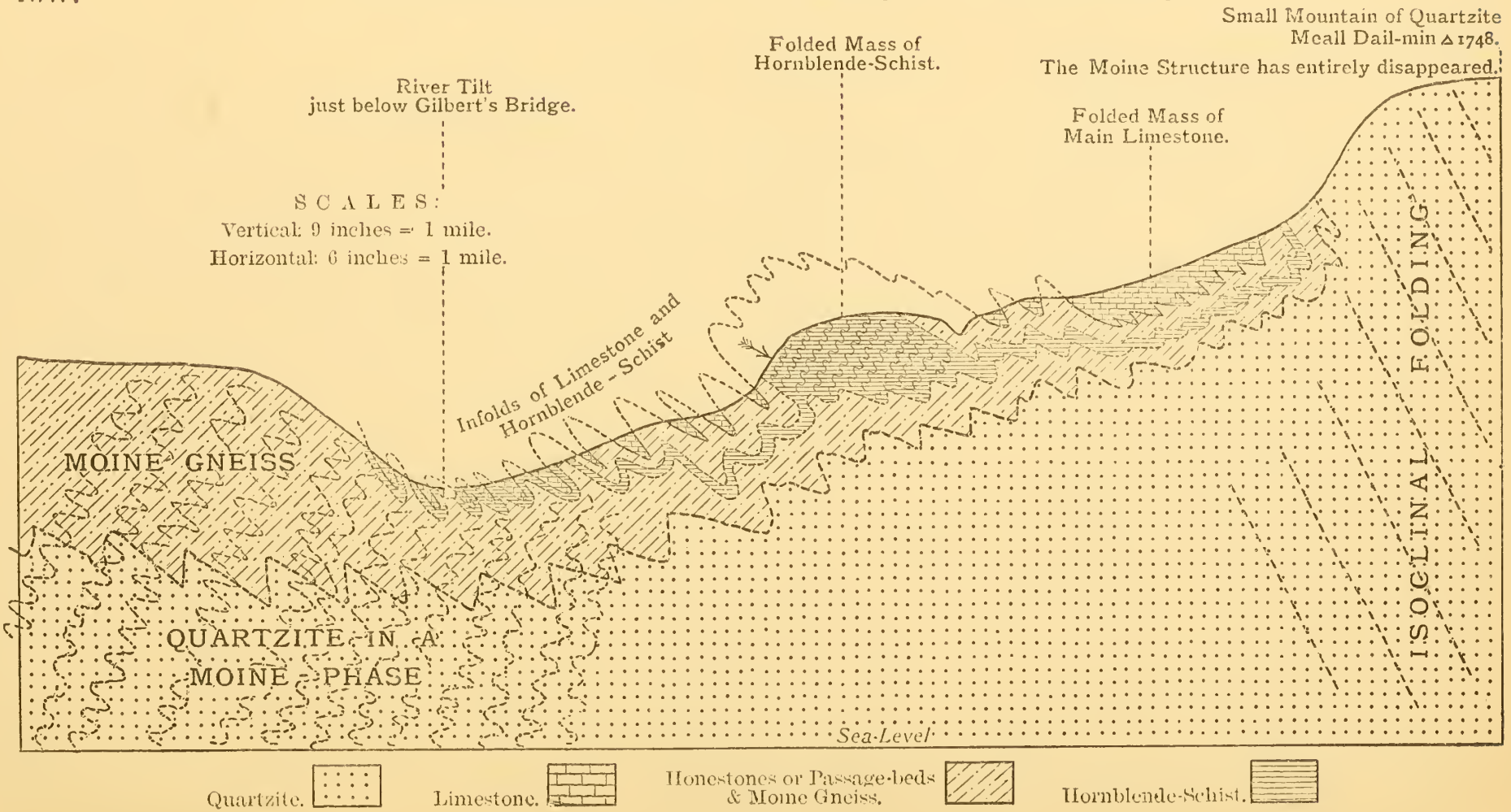
In order to understand the meaning of the maps and section that accompany this paper, it is necessary to realize that the outcrops here shown of such a rock as the Central-Highland Quartzite are not the outcrops of an ordinary bed. They are really the outcrop of a great sheet formed by the repeated folding of a bed on itself, after the manner of the bellows of a concertina when shut up (concertina-structure).

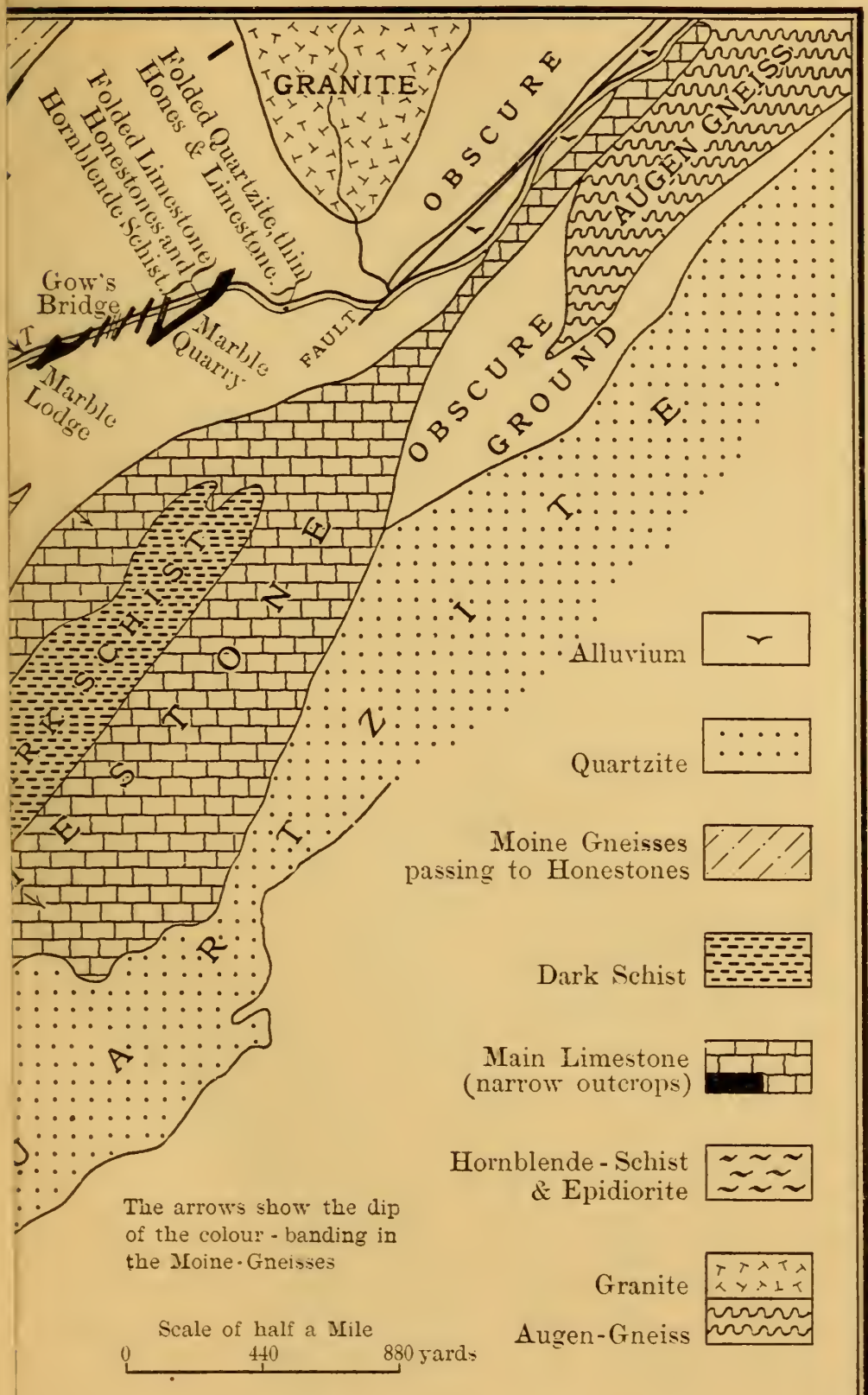
This concertina-structure was produced by the first and greatest folding of the Highland rocks, and to it is due the erroneous idea that the latter were of great thickness originally. A section drawn across the country, after this folding was completed, would closely resemble that drawn through a comparatively-undisturbed area, except that the original beds have to be replaced by these horizontal sheets. The structure has been considerably blurred, in many cases by later movements; but over large portions of the typical 'Moine-Gneiss areas,' this sheet-structure must be still retained, for these gneisses cover an area of several thousand square miles, and must obviously, when viewed on a large scale, be still roughly a horizontal sheet. To the south-east of Glen Tilt these sheets have lost this horizontality, and been thrown into anticlines and synclines that give rise to the ridge-and-valley scenery referred to in the section on the 'Succession in the Braemar Area' (p. 423).

This type of folding, however, attains its full development only in the harder bands, which must, moreover, have a certain thickness before its development is possible. A perfect illustration of these principles is afforded by the little sill of hornblende-schist shown in the section across Glen Tilt (fig. 9, p. 444), the thickness of which has to be greatly exaggerated to enable it to be shown. But in one place, owing to a sudden increase in its original thickness, it was able to fold on itself, and form a homogeneous mass $1\frac{1}{2}$ miles long, and 300 yards broad at the observed outcrop, having a

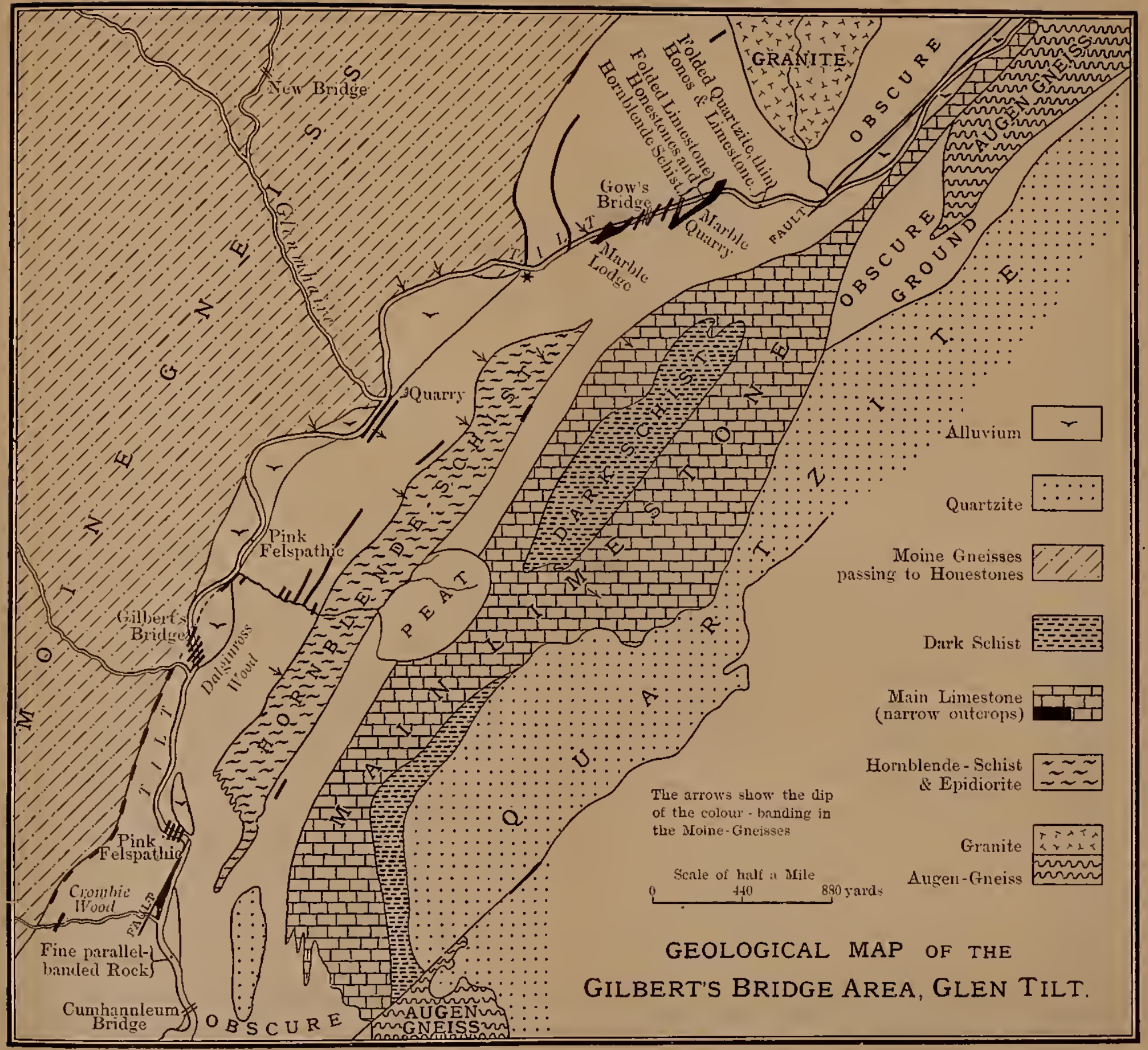
Fig. 9.

N.W. SECTION ACROSS GLEN TILT, passing close to Gilbert's Bridge. S.E.





GEOLOGICAL MAP OF THE GILBERT'S BRIDGE AREA, GLEN TILT.



GEOLOGICAL MAP OF THE GILBERT'S BRIDGE AREA, GLEN TILT.

thickness of at least 100 feet. Over a very large area, however, this little sill rarely exceeds 3 feet in original thickness, and it must often have been less, while its outcrop can in many cases be crossed in a single stride. It is, of course, still repeated by folding, but now it and the associated beds fold together as one little group, or 'entity in the folding,' together building up a sheet, and thus at each complete fold of the group both the top and the base of the little sill are exposed in the outcrops.

Now, just as this sill, owing to its original hardness, folds on itself and forms a homogeneous sheet when it thickens, so the Honestones on the margin of the Quartzite form a similar but larger sheet when they not only thicken to the north-west but were composed of harder material originally. Here, however, the change is no longer local, but is maintained over a very large area.

Later Structures.

In a typical quartzite-mountain the original isoclinal folding is left, and this structure only is shown on the south-east side of Glen Tilt; but as the line along which the Moine Gneisses set on is approached a remarkable buckling structure is set up in the rocks, conveniently known as 'Moine-structure,' shown on the left of the section. It is obviously impossible to say exactly where this structure ends off underground.

Considerable light is again thrown on these points by the little sill where folded on itself. Some little distance north-east of the line of section there is a scar of hornblende-schist, and in this the stages in the formation of the mass can be made out as follows:—

I. The sill was folded on itself to form a large mass free from infolds of the other material (concertina-structure).

II. A fine buckling-structure, reproducing in miniature that of the Moine Gneiss, has been superinduced on the older folding. Specimens showing this can be easily found.

III. A powerful strain-cleavage was set up in the mass, and the cleavage-planes intersect the convex faces of the minute buckles that face the south-east. They never cut those that face the north-west: an important fact, as showing that the crushing movements came from the south-east. This cleavage imparts to the rocks, at first sight, the aspect of a well-bedded mass, with a steady south-easterly dip of some 10° to 20°; but a careful inspection of the scar-face already referred to soon shows how complex the structure and history of the rock-mass really is. Thus study of this sill throws great light on the history of the Moine Gneisses, which cover so large an area to the north-west.

EXPLANATION OF PLATES XXXIII–XXXVII.

Plate XXXIII.

Map of the Gilbert's-Bridge area, Glen Tilt. In this the principal small outcrops of the Main Limestone are shown about the bed of the Tilt. On the hillside above is a large mass of the same limestone, in a much purer phase,

greatly folded. Numerous infolds of Dark Schist occur in this, but they cannot be traced on the ground. A belt of ground to the south-east of the main mass of the Moine Gneisses, within which the passage from Moine Gneiss to Honestone occurs, is left blank. The limit of the main mass of the Moine Gneisses is obtained by joining up the westernmost outcrops of the Main Limestone, which occur as small infolds. The area is typical of the whole district; while the stream-sections are unusually clear, the flanks of the valley are greatly obscured by downwash and patches of Drift, and the boundaries between the different outcrops are often uncertain.

Plate XXXIV.

[For the microphotographs from which this and the following three plates are reproduced, I am greatly indebted to Mr. Hall, of the Geological Survey.]

Fig. 1 (88). First cutting above Struan Railway-station, Garry area. Moine Gneiss with typical granulite-structure. (See p. 406.)

2 (86). Bed of the Garry below Dalnacardoch Lodge. Much microcline; also showing quartz-bleb structure. (See p. 408.)

Plate XXXV.

Fig. 1 (99). Gaick Forest. Inverness. Epidotic gneiss. (See p. 410.)

2 (107). Cairn Fidhleir. Tarf Area. The round-weathering oligoclase-gneiss. (See p. 411.)

Plate XXXVI.

Fig. 1 (84). Bed of the Garry, opposite Dalnacardoch Lodge. Abundant microcline, containing minute quartz-blebs. Green mica and a little plagioclase. (See p. 408.)

2 (136). The Passage-Rocks at Auchallater, Glen Clunie, Braemar. Showing the fine biotite-granulite, always present in the Honestones or Passage-Rocks, and often their dominant constituent. (See p. 424.)

Plate XXXVII.

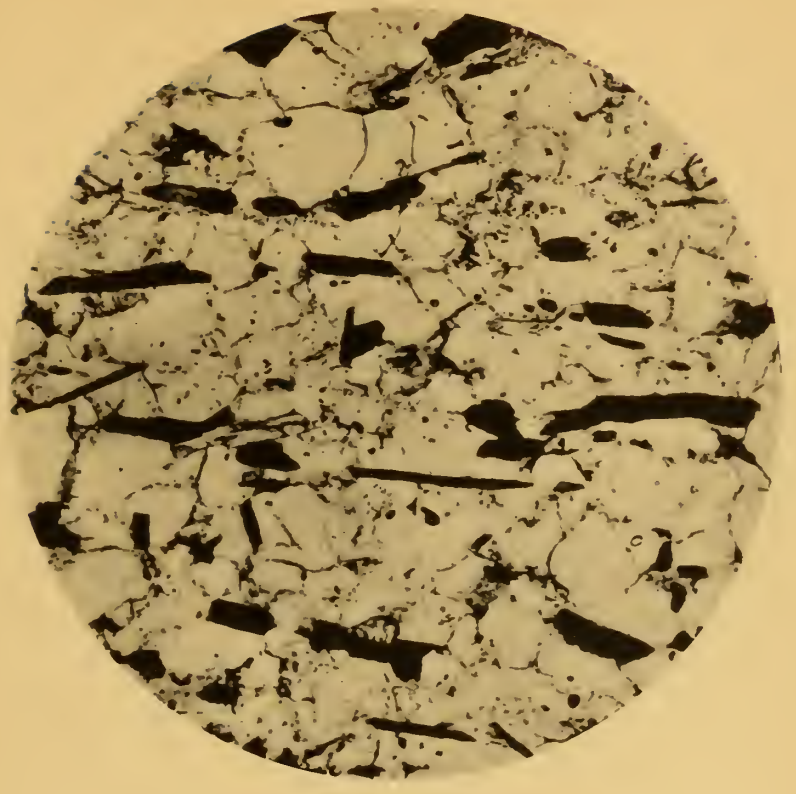
Fig. 1 (113). Just above the road on the west side of Braemar. Highly-quartzose Moine Gneiss, with lines of heavy minerals (see p. 424). This is part, probably, of the Quartzite in a 'Moine-phase.' But it is difficult to say, at this locality, where one rock begins and the other ends: they were obviously all part of the same bed originally.

2 (150) Sron-Dias Crags, upper part of Glen Firnate, south-east of Beinn y Ghlo. An illustration of a slight reversion to conditions of deposition similar to those south-east of the main area of the Moine Gneiss, the rock on the margin of the Quartzite having the composition and structure of a fine Moine Gneiss. (See p. 440.)

Discussion.

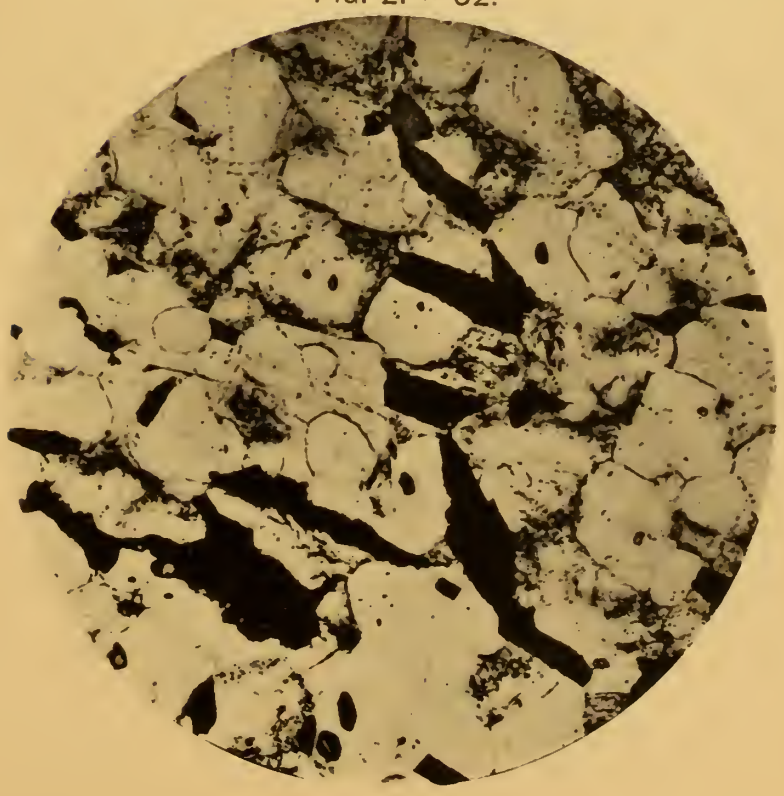
Dr. Horne said that he was glad to have the opportunity of taking part in the discussion, because he had recently visited the sections between Blair Atholl and Braemar under the guidance of the Author, and had the privilege of reading his manuscript now submitted to the Society. He wished to express his high appreciation of the detailed mapping done by the Author, and of his prolonged study of the petrographical characters of the rocks of that region.

Fig. 1. × 32.



No. 88.

Fig. 2. × 32.



No. 86.

G. B. Photomicro.

Bemrose, Collo.

FIG. 1. × 32.

No. 99.

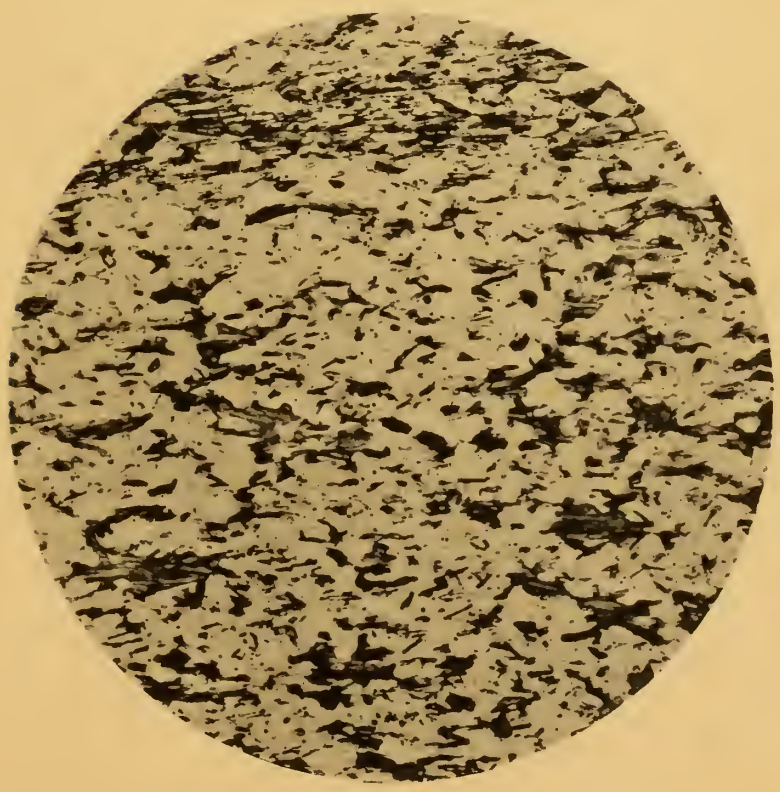
FIG. 2. × 32.

No 107.

Fig. 1. × 32.

No. 84.

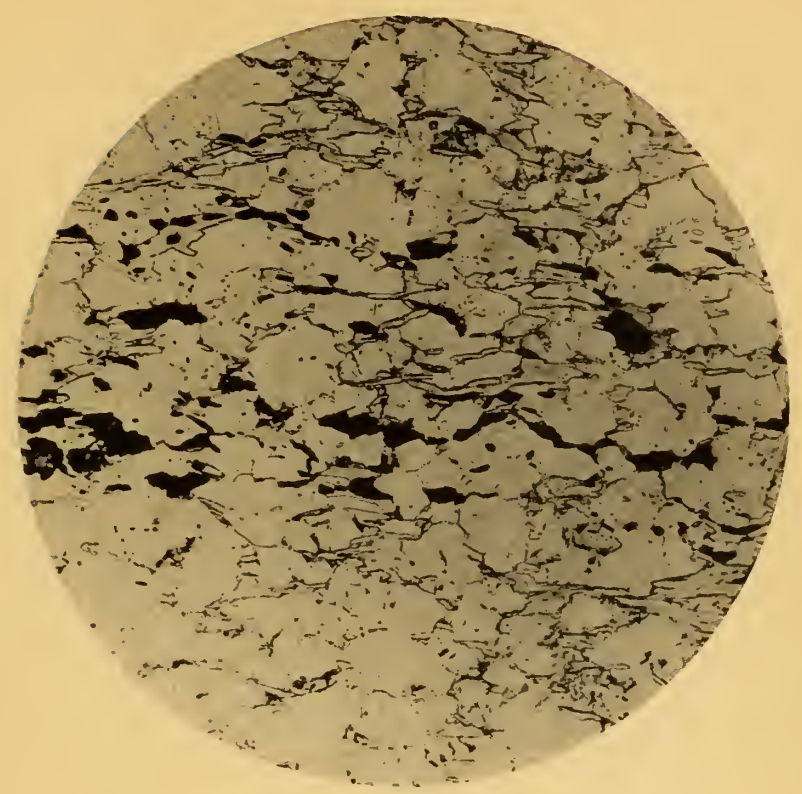
Fig. 2. × 32



No. 136.

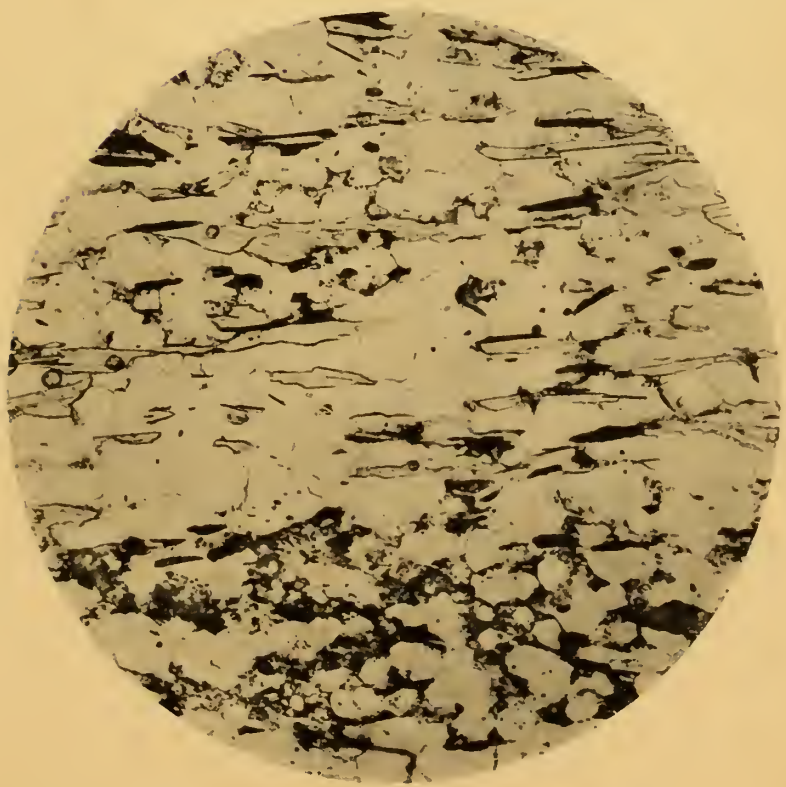
G. B. Photomicro. *Benrose, Collo.*

FIG. 1. × 32.



No. 113.

FIG. 2. × 32.



No. 150.

G. B. Photomicro. *Bemrose, Collo.*

It is now recognized that the granulitic gneisses and mica-schists of Moine type cover wide areas of the Highlands, from the north-west of Sutherland and Ross to the Grampians; and it is further admitted that they represent sediments of siliceous and argillaceous types. The speaker believed that the first part of the paper would form a valuable addition to our knowledge of the petrography of the Moine Gneisses. The second part, dealing with the probable stratigraphical horizon of these altered sediments, raised questions of great interest and importance. Along their north-western margin their boundary is defined by the Moine Thrust, while along their south-eastern limit in the Grampians, where they come into contact with the sedimentary strata of the Eastern Highlands, no such line of disruption had been detected. He agreed with the Author in thinking that no set of faults like that of Glen Tilt and Loch Tay could explain the relationship, for the obvious reason that the Moine Gneisses occur to the south-east of that line of disruption in Perthshire and Aberdeenshire. The Author advanced the ingenious explanation that the Moine Gneisses pass laterally into the Parallel-Banded or Hone-Rock group of the East-Highland sequence which, according to him, lies between the Perthshire Quartzite below and the Little Tremolite-Limestone (or, when the latter is absent, the Blair-Atholl Limestone) above. It had been clearly proved, as contended by the Author, that there is decreasing crystallization of the Moine Gneisses along their south-eastern margin, and it had been further conclusively proved that both the Parallel-Banded series and the Perthshire Quartzite merge into granulitic gneisses along their junction with the Moine Gneisses. Indeed, this feature is so marked that several members of the Geological Survey had drawn a line to guide the colourist, but not a stratigraphical line between the Moine Gneisses to the north and the schistose Dalradian sediments to the south.

Regarding the section at Gilbert's Bridge, in Glen Tilt, it was doubtless true that a band of limestone with dark schists is there repeatedly infolded with the Moine Gneisses, as the Author showed, and the speaker agreed with him in thinking that it represented the Main Limestone of Blair Atholl. Similar evidence had been obtained in the valley of the Tarf, north of the Tilt; while north of the Dee the Blair-Atholl Limestone, the Dark Schist, and even the Perthshire Quartzite, had been found within the area of the Moine Gneisses, and infolded with the latter. The Author's reading of the section at Gilbert's Bridge involved his interpretation of the East-Highland or Dalradian sequence. But some of his colleagues had been led by their detailed mapping to the same conclusion as that of Prof. Nicol, namely, that the Perthshire Quartzite overlies the Black Schist with the Little Limestone. The speaker referred to the transgression of the Quartzite and to the evidence furnished by the Boulder-Bed at Newbiggin, south of Braemar, where it rests upon the eroded edges of the Parallel-Banded series, and is folded over an arch of the Tremolite-Limestone. In the opinion of the speaker, the view that the Quartzite is the highest member of the series, although not free

from difficulties, was a more reasonable interpretation of the sequence than that adopted by the Author. He therefore inferred that the Author had not proved his main point regarding the stratigraphical horizon of the Moine Gneisses. Indeed, he considered it improbable that the latter were represented by a few feet, and at one locality by a few inches of the Parallel-Banded series. The speaker then referred to the resemblance of part of the Moine Series to the pre-Torridonian sedimentary schists north of Loch Maree, and to the development of structures akin to those of the Moine schists in the basal division of the Torridon Sandstone. In conclusion, he expressed the hope that the paper would be published with the necessary illustrations, as it embodied the views of one who had studied the crystalline schists in the areas mapped by him with great energy, enthusiasm, and ability.

Sir Archibald Geikie remarked that, although it had been satisfactorily proved that the main mass of the rocks of the Central Highlands is of sedimentary origin, great difficulties still remained in the determination of their true order of succession. He had had the advantage of traversing some of the Author's ground with him in former years, and could bear testimony to the zeal, capacity, and ingenuity with which he attacked the complex problems which these rocks present. The speaker, however, thought that the difficulties involved in the Author's present theoretical explanation were too formidable, and he preferred the view of the structure of the ground which had commended itself to the rest of the members of the Geological Survey. In the exposition of his paper given by the Author that evening, no reference had been made to the Boulder-Bed which formed so conspicuous a band across the Highlands, although no doubt this band had been fully dealt with in the paper as written. The speaker was disposed to attach great importance to this horizon as a clue to the sequence of the formations. Yet it illustrated some of the perplexing features of the region. Though conspicuous along the northern margin of the central chain of quartzite-ridges, it had not been recognized along the southern margin. But, even along its line of outcrop, it appeared not to be a continuous sheet of conglomerate; it disappeared for considerable distances, and came in again on the same horizon, even as far as the islands of Islay and Garvelloch. Probably it represented a series of local shingle-beaches which were not developed farther south. The paper would be a valuable record of the observations and conclusions of one of the most active and enthusiastic among the workers who had given their time and energy to the elucidation of Highland geology.

Mr. Greenly felt that it was impossible at that late hour to deal with the many points of great interest which were raised by this paper, the question of the relation of the gneisses of Moine type being one of great magnitude. In Sutherland, where the speaker had worked, they certainly appeared to represent a very large formation. He drew attention to the unique opportunity for geological science presented by the work of the Geological Survey

in the Highlands. Tracts of metamorphic rocks with which single workers could deal were too small for general purposes: while the great continental masses of them in other countries could only be sketch-mapped during the lifetime of the present generation. In the Scottish Highlands we had a metamorphic region large and varied enough to be of world-wide interest and application, and yet it could be mapped in great detail, because it was possible to bring the united efforts of a whole staff of surveyors to bear upon it. Herein lay the very great value of the work of the Author and his colleagues, work which might have other applications than those of pure science.

The Author thanked the Fellows present for the kindly way in which they had received his paper. With regard to the suggestion that rocks of various ages might be involved in what may be termed a 'Moine-Gneiss' area by folding, the Author pointed out that the newest or most recent must be older than the oldest intrusion that cuts the folding. As an illustration of this important point, he referred to the Meall-Gruaim 'augen-gneiss' shown on the map to the south of Gilbert's Bridge, and suggested its pre-Torridonian age.